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GAS WORKS, ETC.

PLAN OF GAS WORKS FOR TOWN OF 10,000 INHABITANTS.

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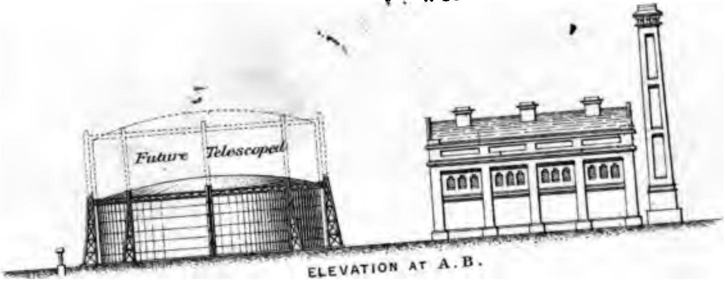

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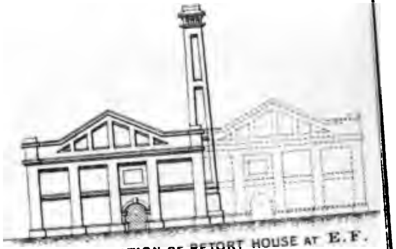

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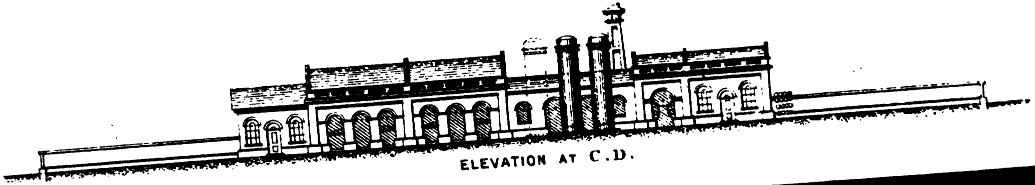

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THE

CONSTRUCTION

OF

GAS-WORKS

AND

THE MANUFACTURE AND DISTRIBUTION OF COAL GAS

ORIGINALLY WRITTEN

BY SAMUEL HUGHES, C.E.

SIXTH EDITION, RE-WRITTEN AND MUCH ENLARGED

BY WILLIAM RICHARDS, C.E.

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PREFACE.

This treatise was originally produced by the late Samuel Hughes, nearly thirty years ago, and by the practical information conveyed, at a price within the means of all connected with the art, it presented an important new feature in the MANUFACTURE AND DISTRIBUTION OF GAS; whilst the various editions issued in the original, and subsequently in a revised form, fully testify to the desirability and popularity of the work.

During the years that this treatise has been before the public, vast alterations and improvements have been introduced into the art it refers to: by which the cost of the production of gas has been reduced one-half, and thus companies have been enabled to decrease its price in a corresponding degree. This again has induced the public to employ gas generally for illumination, so that the present consumption in the United Kingdom, is ten times greater than when this work was first issued.

The successful applications of gas for heating apartments and buildings, for cooking, as well as for producing motive power, are of comparatively recent date; and its superiority for these, as well as for many manufacturing purposes, is beyond all doubt. Indeed, judging from the results of recent inventions, gas as a motor will in innumerable cases not only replace, but supersede, steam-power, on account of its absence from danger, the economy and facility of its adoption, and the various degrees of power that can be obtained by its use; whether no more than sufficient for actuating a sewing machine, or equivalent to that of many horses.

All these facts have rendered a new edition of this work absolutely indispensable; and in accepting the task of its preparation, I decided on re-writing nearly the whole of the work, to omit a number of the old engravings which were of too elementary a character, and to replace them by a larger number more suitable for the purpose.

The absence of uniformity of opinion concerning many points connected with our subject will of necessity—according to the views of some engineers—render the contents of this volume at times in fault. To give only one instance of this diversity of opinion: the Gas Light and Coke Company employ dry meters most extensively for their consumers; whilst there are other Metropolitan and a large number of Provincial companies who have the opposite opinion, and use wet meters only. Therefore, with this glaring instance before us, it is evident that my statements, however accurate, cannot always meet with the entire approval of every reader, and that at times adverse criticism may arise.

I have, however, given with candour the results of many years' experience; and having taken the utmost pains in the production of the present volume, I hope, and believe, that it will be acceptable to all engaged in the Manufacture and Distribution of Gas.

WILLIAM RICHARDS.

January, 1880.

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GAS-WORKS

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OTWITHSTANDING all the wondrous achievements of the ncients, their magnificent monuments and buildings, their culpture, their pottery, and their possession of many valuable arts which have long since been lost, they appear to have been totally unacquainted with the existence of gases. This assertion is confirmed by the absence of any reference being made to them in ancient history, but more particularly by the Scripture, wherein the term smoke is applied alike to the vapours arising from burning bodies, to the breath issuing from the mouth and nostrils, as well as to the vapours from boiling water. Moreover, although in Holy Writ air is frequently alluded to, there is nothing to lead us to suppose that its materiality, weight, or other properties were recognised. Hence, beyond the indefinite word "smoke," we may conclude that the nature of any aëriform body differing from the atmosphere, and even that of the air itself, was in those days unknown.

Gas-lighting is so intimately associated with chemistry, both in its application and progress, that the history of the former can only be treated by referring to the latter; however, our observations on these subjects will be necessarily brief.

The word chemistry is derived from the Greek, signifying the mysterious and dark; and we may assume that this science first had its origin in the study of the metals, to which no doubt it was principally if not entirely confined during many ages; and although in Scripture we meet with one or two modern chemical names, we believe these to occur from an imperfect translation, as is the case with the word "coals," found in the Bible, which material was unknown at the periods referred to, and is in some continental languages rendered as "carbon" or "fuel," or by analogous expressions.

About the twelfth century A.D. the idea was entertained by chemists, or rather alchemists—as the name had been altered by the Arabs—that by certain means within the range of discovery, the baser metals, as lead, iron, &c., could be transmuted into gold and silver. In due time it was believed that for so desirable a purpose, all that was necessary, was to find the "philosopher's stone," which, when obtained, would confer on its possessor not only the power of transmuting metals, but also all happiness, health, wealth, and long life; and, singular as it may now appear, among these alchemists who vainly sought so wild a chimera, were men of the highest order of intellect, and who have in other ways vastly enriched our store of general knowledge. Nor were their researches confined to the transmutation of metals, but they also extended to "Magic," by which it was supposed that any desired object could be attained through supernatural agency, which could be acquired by study.

Possessing as they did the most implicit faith that such inestimable prizes were within their reach, it is not surprising that alchemists pursued their fruitless investigations, and experiments, during several centuries with incredible zeal and perseverance; which were further encouraged, by the repeated assertions of many of their class, who pretended that they had discovered the long-desired secret of transmutation of the metals: whilst one celebrated alchemist was stated to have prolonged his life upwards of a thousand years by means of the virtues of his medicines.

But it is most evident that the primary aim of these philosophers, or enthusiasts, was based on erroneous foundation, without the remotest prospect of success; yet by their invention of crucibles, stills, retorts, furnaces, and other apparatus employed in the modern chemical laboratory, they accomplished much good, and their labours were eventually of considerable value to science.

In the course of time, perhaps owing to the repeated and continuous disappointments in realising their expectations, alchemists began to extend their investigations to more rational pursuits. Among the earliest and most celebrated of these was Basil Valentine of Erfurth, who lived about the middle of the fifteenth century, and who by many is regarded as the founder of the modern science of chemistry. After him followed Paracelsus and Van Helmont. In the works of Valentine are described the first accurate and intelligible directions for the preparations of nitric, muriatic, and sulphuric acids. On producing nitric acid he termed it the "water" or the acid "spirit of nitre." It was afterwards called aquafortis; and, when combined with muriatic acid, its property of dissolving gold, is mentioned by that author.

Paracelsus, who was regarded as a physician of wonderful ability, and is mentioned by Shakespeare in *All's Well that Ends Well*, was the first to obtain gas by the action of dilute acid on limestone; but he failed to appreciate the importance of his discovery.

Van Helmont was a native of Brussels, and born in 1577. He first directed his attention to the studies of alchemy and magic, both of which were then cultivated as higher branches of education; but it is needless to say that they were alike founded on error and falsehood. These he left in disgust, and subsequently devoted himself to the study of physics generally, at which he laboured during the greater portion of his life, but it was not until after his death that his valuable researches were made known.

Among the discoveries of Van Helmont, was the existence of certain aëriform bodies which differed entirely in their nature from atmospheric air. These he observed were produced by fermentation, combustion, and the action of acids on limestone; which he at first called "spirit," a term then generally applied to all things invisible. In one of his experiments he burnt 71 lbs. of charcoal, which yielded but 1 lb. of ashes, and he concluded that the other 70 lbs. served to form the "spirit." Van Helmont observes, "There are bodies which contain this spirit of which they are almost entirely composed, and is therein fixed and solidified, and are made to leave that state by fermentation, as we observe in the fermentation of wine." He remarks, "This spirit, up to the present time unknown, not susceptible of being confined in vessels, nor capable of being reduced to a visible body. I call by the new name of 'gas,'" which name is believed to be derived from the Flemish word "geest," a spirit.

Van Helmont further distinguished himself by his experiments on air, of which he acquired a tolerably accurate opinion respecting its weight and elasticity; but most remarkable among his statements is that "flame is produced by ignited vapours." The same opinions were expressed many years afterwards by Sir Isaac Newton and Volta. Neumann, a chemist of the middle of the eighteenth century, also describes how that when pitch was held over a flame, it emitted a vapour which took fire from a lighted paper. These statements show the very gradual progress towards the development of gas-lighting.

The first recorded instance of producing and storing a gas, is that given by the Honourable Robert Boyle, who, possessing an ample fortune, devoted himself to scientific investigations. He describes one of his experiments in which a number of iron nails were placed in dilute acid, when a quantity of "air" was evolved. This he considered to be atmospheric air produced artificially, but which was subsequently ascertained to be hydrogen gas.

All the chemists of the middle of the eighteenth century refer to the spirit obtained by distilling wood, which they termed "fixed air," implying air that had been fixed in the substance prior to distillation; some of whom express their surprise how a body could possibly contain a quantity of air two or three hundred times greater in volume than the material from which it was derived. At the epoch in question the word "damps," from the Dutch, signifying vapours, was introduced into the English language. These are described "as noxious and even fatal exhalations or vapours, which infest subterranean places, and particularly if the air be not frequently renewed." Hence "choke-damp" refers to suffocating vapours, as carbonic acid gas; and "fire-damp" to explosive compounds.

Burning fountains, arising from inflammable gas issuing from the earth, have existed from remote ages, and, being attributed to supernatural agency, they were worshipped as emblems of the Deity. However, these we now know to occur from natural causes, arising from coal or other bituminous substances having been buried by earthquake, or similar means, at such a depth as to be distilled by the heat existing in the interior of our globe; by which the escaping gases were expelled through fissures of the earth, and being ignited accidentally, or by lightning, the burning fountain was produced.

To a similar cause is due the supposed burning spring mentioned by Mr. Shirley in the "Philosophical Transactions" of 1667, entitled, "A Description of a Well and Earth in Lancashire taking Fire by a Candle approached to it." In this the author explains that his attention was directed to a spring near Warrington, where it was stated that "the water did burn like oyle." He says, "This boyling I conceived to proceed from the eruption of some bituminous or sulphurous fumes. Then applying my hand to the burning place of the water, I found a strong breath as it were, a wind to blow against my hand. The fumes when they broke out of the earth and prest against my hand were not to the best of my remembrance at all hot." The author then caused a dam to be made around the burning place and the water to be drawn off, when, on applying the burning candle to the surface of the dry earth, "the fumes took fire and did burn very bright and vigorous."

Subsequently the attention of the Rev. Dr. John Clayton was directed to a well in the same neighbourhood as that observed by Shirley (near Warrington), and it is probable that in both cases the same locality was examined, "when after having caused a hole to be dug, on the candle being put down into the hole, the air catched fire and continued burning." This circumstance appears to have suggested to Dr. Clayton the idea of making some experiments in the distillation of coal, as he says, "I got some coal and distilled it in a retort in an open fire. At first there came over only phlegm" (steam), "afterwards a black oil, and then likewise a spirit" (gas) "arose, which I could in no ways condense, but it forced my lute, and on coming close thereto to repair it, I observed that the spirit which issued out caught fire at the flame of the candle, and continued burning with violence as it issued out in a stream, which I blew out and lighted alternately several times. I then filled a good many bladders therewith, and might have filled an inconceivable number more, for the spirit continued to rise for several hours, and filled the bladders almost as fast as a man could have blown them with his mouth; and yet the quantity of coals was inconsiderable.

"I kept this spirit in the bladders a considerable time, and endeavoured several ways to condense it, but in vain; and when I had a mind to divert strangers or friends I have frequently taken one of the bladders and pricked a hole therein with a pin, and compressing gently the bladder near the flame of a candle till it once took fire, it would then continue flaming till all the spirit was compressed out of the bladder; which was the more surprising because no one could discern any difference between those bladders, and those that are filled with common air."

The exact date of these experiments is not known, but they are supposed to have been made about 1690, and in the account of them we have clearly described the first attempts at distilling coal, producing and storing gas, and obtaining light therefrom. However, many years elapsed before these operations were practically applied.

From the "Vegetable Staticks," by Dr. Hales, published in 1726, we learn, from his "Analysis of Air," that he experimented with innumerable substances in order to ascertain the quantity of "air" given off by them in the process of destructive distillation, as it is now termed. But it is evident throughout that he is in doubt whether this air is similar to that of the atmosphere. Among the numerous experiments he states, that in one operation he obtained 180 cubic inches of air from 158 grains of Newcastle coal. The apparatus described by him consists of a retort made of a musket barrel, to which was attached a pipe bent at an acute angle, the extreme end of which entered the reservoir under water. Thus the air, or gas, in the course of production, forced a passage for itself through the water before entering the reservoir, which was a great progressive step in pneumatic chemistry.

In this remarkable work we meet with the observation by Sir Isaac Newton, "All flaming bodies, as oil, tallow, wax, wood, fossil coals, by flaming, waste and vanish into burning smoak, which smoak, if the flame be put out, is thick and visible, and sometimes smells strongly, but in flaming loses its smell by burning, and red hot smoak can have no other appearance." Here we have a very close approach to the knowledge of inflammable gas being a distinct and separate body, which to this time was not understood. That great philosopher Newton asserted his opinion long before the discovery of oxygen, or the nature of carbon, or hydrogen, was recognised, that the diamond consisted of combustible matter; and he suspected the existence of an inflammable element in water; both of which opinions have been verified in a remarkable manner, as the combustion of the diamond was effected by Lavoisier, thus proving it to be carbon; whilst hydrogen, first produced by Boyle, is one of the components of water.

A few years afterwards, namely, in 1733, we find in the "Transactions of the Royal Society" a communication from Sir James Lowther on the inflammable air issuing from the shaft of a coal-mine near Whitehaven. The workmen were surprised on sinking to the depth of forty-two fathoms to find a rush of air taking place, which caught fire from the flame of a candle and burnt with great intensity, making a blaze about three feet in diameter and six feet high. Several experiments were made on this flame by the steward and others, who successively caused it to be extinguished by beating it down and smothering it with the colliers' hats and again lighting it. At length the heat communicated by the flame was found to be very inconvenient, as it warmed the pit to a high degree, and it was necessary to have recourse to water in order to extinguish it. After this the gas was not again allowed to be lighted till the sinking had proceeded down to a depth of several feet below the bed of coal through which the gas first made its appearance. The part of the pit at which the gas escaped was then securely walled off, and a tube about two inches in diameter extended up the shaft to a height of twelve feet above the surface of the ground. Through this tube the gas was allowed to escape into the open air, which it continued to do in undiminished quantity for several years. Many observations and experiments were made on the gas which was thus discharged from the extremity of the tube. It was collected in bladders, tied up, and preserved for many days. When a small pipe was fixed in the mouth of the bladder, and the gas gently pressed out against the flame of a candle by squeezing it, it was observed to take fire, and to burn so long as the bladder was gently squeezed and the gas expelled. This experiment on gas which had been so confined nearly a month was made in the presence of the Royal Society. It was stated that when it first issued from the top of the tube the gas was as cold as frosty air, and that it would not take fire from a spark, but required a flame to ignite it.

Here, again, from the cause already mentioned, carburetted hydrogen was emitted from the earth, without, however, conveying any useful lesson.

In Neumann's "Chemistry," published in 1759, he states that inflammable vapours may be collected and preserved in bladders, which "after keeping for several weeks a little of the vapour forced out near a candle instantly took fire as at first," thus demonstrating the permanent nature of the gas.

In 1764 a communication was made by Mr. Jessop to the Royal Society of London, wherein he related an accident that occurred to a workman in a mine in Yorkshire, who descended with a torch in his hand, when suddenly an explosion occurred, accompanied by a vibration of the earth, and the man was severely burnt. Various other instances are recorded of these emissions of carburetted hydrogen, which on combining with atmospheric air forms an explosive compound. In modern times such accidents are unfortunately of too frequent occurrence.

Dr. Watson, in his "Chemical Essays," published in 1767, mentions an experiment on the distillation of coal, in which he takes into consideration the residuals only obtained, without any reference to the quantity of "air." He says, "During the distillation there was frequent occasion to give vent to an elastic vapour, which otherwise would have burst the vessels employed in the operation." In the experiment he lost upwards of a third of the weight of the coal, and continues, "The matter which is lost during the distillation of both wood and coal has been called *air*, and it certainly has one at least of the most distinguishing properties of air, permanent elasticity, for bladders may be filled with it as with common air." He further remarks that the air was inflammable even after it had been made to pass through three large vessels of water.

Hitherto so far as regards gases all had been conjecture, for although Van Helmont affirmed so positively their existence, yet he failed to demonstrate the fact. Boyle in producing hydrogen believed it to be atmospheric air. The observations of Shirley and the comprehensive experiments of Clayton led to no profitable results. In the numerous investigations of Dr. Hales the word "air" only is retained, and from his description he appears to believe that in all cases air similar to that of the atmosphere was disengaged; whilst Dr. Watson states positively that the matter which is lost during the distillation of both wood and coal has been called "air." However, it should be observed that some chemists made a distinction between the two kinds of inflammable air, as hereafter mentioned in an extract from a work by the celebrated Dr. Priestley.

In Macquer's "Dictionary of Chemistry," published in 1771, we find inflammable air called "gas," adopted from Van Helmont. There it is stated, "Gas is a name given by chemists to the volatile invisible parts which escape from burning bodies." The term was, however, very tardily admitted into the English language, insomuch as in Nicholson's "Dictionary of Chemistry," published in 1804, the original term "inflammable air" is retained.

We now arrive at the most remarkable epoch in the whole history of chemistry, when Black, Priestley, Cavendish, Rutherford, Lavoisier, Scheele, and others made their wondrous discoveries. And we are struck with amazement when we reflect on the immense knowledge acquired by these few illustrious men in so brief a period, which revealed to us some of the grand secrets of Nature, and changed the interpretation of the word chemistry, from darkness and mystery, to light and intelligence.

From the same source as first proposed by Paracelsus—that is from lime by the action of acid—Dr. Black of Edinburgh, in the year 1755, produced carbonic acid gas. This he also designated "fixed air," and on examining its properties he found it entirely different in its nature from atmospheric air: which is the first recorded instance of gas being produced with a positive knowledge of its properties acquired. About 1766 Dr. Macbride, of Dublin, verified the experiments of Black, and ascertained that a portion of fixed air (carbonic acid) existed in the atmosphere.

The following year Cavendish invented the pneumatic trough, and studied the properties of the gas (hydrogen), first produced by Boyle.

In 1774 Dr. Priestley discovered the gas oxygen, and subsequently ascertained, that it was a component of our atmosphere, which was the most important event that ever occurred in the annals of chemistry. Scheele about the same period made a very similar discovery.

About this time Dr. Rutherford ascertained the existence of another elastic fluid in the atmosphere, differing in its nature from oxygen, or carbonic acid; and yet, like the latter, it was incapable of supporting combustion; and thus was discovered nitrogen.

Lavoisier in 1775 demonstrated the composition of atmospheric air, and six years afterwards, water was discovered by Cavendish to be composed of the hydrogen of Boyle, and the oxygen of Priestley. The decomposition of water into its two elements was made very shortly after by Lavoisier, one of the greatest men that ever France produced. The cause of combustion then became to be understood, when the errors of the phlogiston theory, which had been entertained for nearly a century, were dispelled.

Nevertheless, with all these great achievements, little was accomplished towards the realisation of gas-lighting, as is made strikingly evident by the following extracts from Dr. Priestley's "Experiments and Observations on different Kinds of Air," published 1790.

In this the author says, "There are different kinds of inflammable air, as has been observed by most persons who have made experiments with air. That which is commonly observed is, that some of them burn with a flame, which may be called a 'lambent flame,' sometimes blue, sometimes yellow, and sometimes white, like the flame from wood or coal or a common fire; whereas another kind always burns with an explosion, making more or less of a report when a lighted candle is dipped into a jar filled with it. Of the latter kind is that which is extracted from metals by means of acids, &c., and of the former kind is that which is expelled from wood, coal, and other substances by heat. It is observable that when wood is heated in an earthen retort, the first portion" (of inflammable air) "burns with a lambent white flame, like that from burning wood in an open fire."

From the preceding we learn how closely the art of gas-lighting was approached, more particularly in the experiments of Dr. Clayton and the observations of Sir Isaac Newton; but there was still wanting the master mind to suggest the means of carrying it into practical operation, by storing the gas and conducting it through pipes to any point where it might be desired to give light and heat; and this great merit was due to Murdoch.

Mr. William Murdoch was an engineer at Redruth in Cornwall, and in the year 1792 he first entertained the idea of employing gas to replace candles and lamps. He subsequently made various experiments on different kinds of coal, with the view of arriving at the means of depriving the gas of its impurities, together with the best method of burning it. We are further informed by Matthews that "he had bladders filled with gas to carry at night, with which and his little steam carriage running on the road he used to astonish the people there." That Murdoch was a man of great abilities there can be no doubt, but the construction of the steam carriage is exceedingly questionable, as such an innovation at that time would have excited universal attention. Besides, he makes no mention of it himself.

Previous to the year 1781 the only means of retaining gases were with bladders—some of which were arranged to act automatically—or with pneumatic jars; but at the period stated, the great French chemist, Lavoisier, invented the gas-holder, substantially as now applied in all gas-works. The first publication of this invention in English was made in 1789, from which circumstance some authors date the invention from that time; and it is by no means improbable that the description of the apparatus in question coming under the notice of Murdoch impressed him with the practicability of applying gas for lighting; but whether due to this circumstance or not, the merit of first employing gas for that purpose, is beyond all question due to that gentleman.

From Dr. Henry's statement, it appears that, in 1792, Murdoch actually lighted his own house and office at

Redruth with gas. He distilled the coal in iron retorts, and conveyed the gas through tinned iron and copper tubes to a distance of seventy feet. He used portable gas, carrying it about with him in a bladder, or in bags of leather or varnished silk, also in vessels of tinned iron fitted with a small metal tube and stop-cock, through which the gas, issuing from a minute orifice, was ignited, and made to serve as a lantern in travelling backwards and forwards between the mines and his own house.

Murdoch at this early period made many experiments on various kinds of coal, as the Swansea, Haverfordwest, Newcastle, Shropshire, Staffordshire, and some kinds of Scotch coal. He also tried numerous forms of burners, varying in many ways the shape and disposition of the orifices for the emission of the gas. Thus in some burners the gas was allowed to issue from many very minute openings, forming a rose like the head of a watering-can, while in others it was thrown out in long thin sheets, and again from circular openings on the principle of the argand-burner. His attention was also directed to the necessity for purifying the gas, and he certainly adopted the expedient of passing it through water, but does not appear to have made use of lime, the first application of which to the purpose of purifying, appears due to Dr. Henry and Clegg. Murdoch pursued his experiments on the gas from coal, peat, wood, and other inflammable substances, at such intervals of leisure as his numerous other avocations would permit, principally with the intention of avoiding the disagreeable odour peculiar to it.

About 1796 Murdoch communicated to James Watt, jun., son of the celebrated James Watt, the engineer, his views of employing gas as a substitute for lamps and candles, and suggested that a patent should be obtained for that object. This proposal was not, however, entertained by Watt, on account of the heavy expenses his father had incurred a short time previously, in defending some patents in connection with the steam-engine.

In 1798 part of the Soho engine works was lighted with gas, when Murdoch exhibited his experiments to a few friends, who, in after years, when his pretensions to priority in the adoption of gas were disputed, gave their testimony, and proved the entire justice of his claims.

The French engineer Lebon, in 1799, obtained a patent in France for an economical method of employing fuel. In the specification is given simply a description of the accompanying drawing, which shows a retort with its corresponding furnace and pipes for conveying away the products of distillation, without any further explanation, beyond stating the materials that might be employed. The circumstance of Lebon possessing this patent has caused French authors to award him the merit of priority in the application of gas. Two years afterwards that gentleman obtained a certificate of additions to the patent already mentioned, in which he describes the method of producing and burning gas, also the means of obtaining motive power therefrom.

In 1801 the brother of James Watt being in Paris, wrote, saying, "that if anything were to be done with Murdoch's gas it must be done at once, as there was a Frenchman in Paris who had similar ideas, and proposed to illuminate that city by these means." However, from some unaccountable cause, the patent was never applied for; and it may be assumed that neither Watt nor Murdoch had the slightest conception of the gigantic industry they were on the threshold of establishing.

On the occasion of the proclamation of peace in 1802 a public exhibition of gas-lighting was made at the Soho foundry; and Matthews, an eye-witness, states, "The illumination of the Soho works on this occasion was of the most extraordinary splendour; the whole of the front of that extensive building was ornamented with a great variety of devices that admirably displayed many of the varied forms of which gas-light is susceptible. This luminous spectacle was as novel as astonishing, and Birmingham poured forth its numerous population to gaze at and admire the wonderful display of the combined effects of science and art." Murdoch, however, had many difficulties to overcome before he attained the perfection exhibited on this occasion, but he united sound scientific knowledge with great practical skill, and his perseverance enabled him to triumph.

In this year Lebon, already mentioned, had his house in Paris illuminated by gas, and numbers of people of all classes witnessed it with wonder and amazement. At the same period Winsor, who afterwards did so much for the advancement of gas-lighting, being at Brunswick, saw an account concerning the manufacture of Lebon's gas for illuminating purposes, which had been read before the French Institute; and, to use his own words, employed five years after, "the thought struck him like an electric shock." Winsor translated the communication into German and English, which he published as a pamphlet. He also carried out a series of experiments in connection with gas-lighting by distilling wood, &c., before the Duke Regent, Charles William Ferdinand, and his court. And the same year he came to England (undoubtedly entirely ignorant of what had been achieved by Murdoch), with the intention of carrying the new enterprise into operation.

In January, 1804, Winsor first publicly exhibited, at the Lyceum Theatre, in London, the system of illumination by gas. Here he delivered lectures on the subject, which he illustrated by a variety of interesting experiments. Amongst them he showed the means of conveying gas from one part of a building to another, and by the employment of different burners was enabled to display the various forms which might be given to its flame. He also proved, in a very elaborate manner, the various advantages of gas-lighting and its superiority over all other artificial light, all of which time and experience have fully confirmed.

In 1802 and 1803 Murdoch erected works for the supply of gas to the premises of Messrs. Boulton and Watt; and in 1804 Mr. George Lee, of the firm of Messrs. Phillips and Lee, of Manchester, had his dwelling lighted by gas in order to test its salubrity, previously to its adoption in the cotton-mills of the above-mentioned firm; and the following year the mills alluded to were so lighted. Mr. Lee's evidence afterwards contributed considerably towards overcoming the prejudice which existed against gas-lighting, and to demonstrate its advantages and economy.

In his paper of 1805, describing the method of lighting these mills, which was published in the "Philosophical Transactions" for 1808, Murdoch does not particularly mention the process which he followed in making the gas, but merely states that the coal is distilled in large iron retorts, and that the gas as it issues from them is conveyed by iron pipes into large reservoirs, or gasometers, where it is washed and purified, previous to its being conveyed through other pipes or mains, to the mills. He describes the burners with some minuteness, which were of two kinds—one on the principle of the argand lamp, and resembling it in appearance; the other a cockspur burner, consisting of a small curved tube with a conical end, having three circular apertures or perforations about one-thirtieth of an inch in diameter, one at the point of the cone, and two lateral ones. The gas issuing through these apertures forms three divergent jets of flame, somewhat like a *fleur-de-lis*. The whole of the burners erected in the cotton-mills amounted to 271 argands, each of which gave a light equal to four mould candles of six to the pound, and 633 cockspurs, each of which gave a light equal to two and a quarter of the same candles. The quantity of tallow consumed by each candle was at the rate of four-tenths of an ounce, or 175 grains of tallow per hour.

In his details of the comparative cost of lighting this establishment with gas, as compared with candles, Murdoch's comparison is very much in favour of the former. Taking an average of two hours per day throughout the year, the expense of candles would be £2,000 per annum, while the cost of gas, including every expense of wear and tear and interest on capital, did not exceed £600 a year. On an average of three hours per day the comparison is still more in favour of gas, the expense of candles in this case being £3,000 a year, while that of gas, estimated as before, would only amount to £650.

During his experiments, in erecting his earlier apparatus, Murdoch tried various forms and means of placing the retorts. The earliest kinds were placed upright, with various contrivances for extracting the coke which remained after the expulsion of the gas. However, many inconveniences attended this, as well as other means of "setting" in which the retorts were placed in an inclined position, but in due time all the other contrivances gave place to the horizontal retort, which is the mode of setting universally adopted at the present day.

About the years 1804 and 1805 we find the subject of gas-lighting taken up by eminent chemists, such as Dr. Henry of Manchester, who ably illustrated the mode of making gas in his lectures, and showed how readily and economically it might be used as a substitute for oil and candles. At this time also we find Mr. Clegg, an able mechanician, also engaged in the same establishment as Murdoch, where he entered as a pupil of Messrs. Boulton and Watt, devoting all his energies to the mechanical appliances connected with the successful application of gas.

Clegg appears to have struck off in the same direction as Murdoch, and to have embarked about the same time in the erection of private gas-works for cotton-mills and other establishments. Thus he was engaged in lighting the cotton-mill of Mr. Henry Lodge at Sowerby Bridge, near Halifax, at the same time that Murdoch was erecting his works at Messrs. Phillips and Lee's mill. Indeed, Clegg, jun., states, on the authority of his father's journal, that the mill at Sowerby Bridge was lighted a fortnight earlier, than the one under Murdoch's direction.

In the following years, 1807 and 1808, Clegg proceeded to erect gas-works at various other mills, also at the Catholic College at Stonyhurst, in Lancashire, where he first introduced the system of purifying the gas from carbonic acid and sulphuretted hydrogen, by passing it through lime in a separate vessel. Clegg first used lime as a purifying agent by placing it in the tank of the gas-holder, and applied an agitator to keep it in motion; but the difficulty of removing the saturated material eventually led to its abandonment, and the adoption of a separate vessel.

In 1808 Murdoch communicated to the Royal Society a very interesting account of the successful application of coal-gas to lighting the extensive cotton-mills of Messrs. Phillips and Lee, of Manchester; for this communication Count Rumford's gold medal was presented to him. The following year Clegg communicated to the Society of Arts his plan of an apparatus for lighting manufactories with gas, for which he received a silver medal. About the same period he erected a gas apparatus for a manufactory at Coventry.

In May, 1804, Winsor obtained a patent for "an improved oven, stove, or apparatus, for the purpose of extracting inflammable air, oil, pitch, tar, and acids from, and reducing into coke and charcoal, all kinds of fuel, which is also applicable to various other useful purposes."

"A metal, brick, or earthen stove, oven retort, or vessel, is so constructed to reduce by means of fire and heat all raw fuel of any kind into coke and charcoal, without any or little consumption of the fuel, by which operation the smoke being extracted from all raw fuel, is thus conducted through cold air or water into a condenser, where, after being sufficiently cooled and purified, it undergoes a natural chemical resolution into tar, pitch, oil, acid, ammonia, and inflammable gas or air.

"The inflammable gas or air may be led in a cold state through tubes of silk, paper, earth, wood, or metal, to any distance, in houses, rooms, gardens, places, parks, and streets (and other places), to produce light and heat, or for any other purpose, such as for increasing and multiplying force and power." This was the first patent obtained in connection with gas-lighting.

Having this patent, Mr. Winsor described himself as the discoverer, inventor, and patentee of gas-lighting, and agitated the necessity of forming a company for its full development, so that the streets, shops, and private dwellings should enjoy its advantages; but gas-lighting, like every other great innovation, was looked upon by the public with excessive distrust. In the event of its success, several branches of industry and commerce were doomed to suffer; many interests were, or supposed to be, at stake; some of the chemical properties of gas were unknown; great doubt existed as to its safety, and fears as to its salubrity; indeed, the danger of explosion was magnified to the extent that it was asserted and believed, that a town could be destroyed by the explosion of the main pipes in the streets; and interested parties, in order to prevent the establishment of gas-lighting, did not scruple to appeal to the naval glory of the nation, and this shortly after Nelson had achieved his great victories. "If," said the opponents of the new light—"if this becomes successful, then our naval supremacy is gone, for at present we obtain principally our artificial light from the whale fisheries: these are the nurseries of our best sailors; therefore, if we destroy the one the other must be affected; if the fisheries no longer exist our navy must degenerate."

These objections and arguments were put forth frequently by the journals; and Winsor, who by this time had become intimately associated with gas-lighting, and in a manner constituted himself its champion, met them with that extraordinary courage, perseverance, and zeal which so strongly characterized him; but it is to be regretted that although a gentleman of superior intelligence—with the great qualities already awarded him—he lacked the scientific knowledge so essential for the fulfilment of his undertaking, and unfortunately he was not aware of this deficiency. He boldly combated all possible objections with unexampled ardour, but often committed the most egregious errors, at one time asserting that our atmosphere in its pure state was too powerful, and that a mixture of coal-gas rendered it more salubrious; again, that gas would not explode when intermixed with air, and that its adoption would purify the atmosphere; whilst the prospectus issued by him contained most extraordinary, exaggerated, and fabulous accounts of the enormous profits to be derived from gas-lighting. All this combined to retard his progress, and had he been of a less sanguine nature his task would have been comparatively easy. These errors often brought down upon him the greatest ridicule, in which some of the leading scientific journals took prominent part; but, undaunted, he still persevered.

At length, after having struggled during three years single-handed, and, as it were, against the opinion of the world—having by his letters, pamphlets, and lectures proved the advantages of gas—Winsor succeeded, in 1807, by means of subscribers, in obtaining a capital of £20,000 preliminary to the formation of a company; which sum was intended to demonstrate the practicability of manufacturing and supplying gas on a large scale, also for the purpose of establishing a company, and obtaining a royal charter.

He then occupied extensive premises in Pall Mall, on the site of the present Carlton Club. On the basement were the gas manufacturing and other apparatus to illustrate his lectures, demonstrating the practical utility of gas for lighting, heating, and cooking, also its safety and salubrity; the public on certain days having free access to take cognisance of the process. From these premises a pipe was laid in Pall Mall to the corner of St. James's Street westward, and to the Haymarket eastward, with lamp-posts at short intervals, including several in front of Carlton House, the residence of the Prince Regent; on the 28th of January, 1807, one side of Pall Mall was lighted by gas, and on the King's birthday, June 4th, both sides were thus illuminated, and continued so during the sessions of Parliament of 1809 and 1810, whilst endeavouring to obtain an Act of incorporation and charter; this being the first public street ever lighted by gas.

The intention of Winsor and his subscribers, or shareholders, in 1808, was to establish a company, and obtain a royal charter or exclusive privilege for lighting all the British possessions by gas; for which purpose they proposed a capital of one million sterling. A memorial was accordingly presented to the King, setting forth the advantages anticipated from the innovation, and the production and general employment of coke, praying for the concession; but after the question had been duly considered in Privy Council, it was decided that his Majesty could not grant the charter of incorporation until a Bill had been obtained from Parliament, authorising the company.

The following year Winsor and his shareholders again applied, with more moderate pretensions, to be established as the "National Light and Heat Company," but were strongly opposed by Murdoch. On this occasion many witnesses were examined before a committee of the House of Commons, who proved incontestably that gentleman's claim, to priority of adopting gas for illumination. The evidence given is of the greatest interest; and the merits of Murdoch caused the application to be refused.

Amongst Winsor's subscribers were some eminent men of the day, and, like himself, of the greatest perseverance and zeal. They had already been too familiar with difficulties to be discouraged by defeat; and again, in 1810, they applied to Parliament, and succeeded in obtaining an Act of incorporation as "The Gas-light and Coke Company," with a capital of £200,000. But the enterprise was looked upon as so visionary, that it was asserted, this

Act was granted in order to make a great experiment of a plan of such extraordinary novelty.

The royal charter was granted to the company in 1812; but the privileges accorded by that charter were neither liberal nor encouraging, for by it, the company had no exclusive right to prevent any other persons or company from entering into competition with them. The power and authority granted were very moderate; and whilst the company were under severe restrictions, they were confined to the metropolis, and were liable to have the charter annulled if they failed to fulfil their obligation.

The very prominent part taken by Winsor in establishing gas-lighting has often been passed over, whilst his errors, the result of a very sanguine mind, have been displayed with all vigour. Peckston only does him justice when he says, "Sanguine in his expectations, indefatigable in his exertions, and zealous in his cause, he directed all the talents and energy he possessed to the one great object, and thus achieved much for the public good; but with all his ardour, his skill, and his exertions, he, like many others, achieved but little towards promoting his own comfort, or the comfort of his family."

The Gas-light Company being thus legally established, they commenced their operations at a wharf and premises on a part of the site now occupied by the Civil Service Institution, in Cannon Row, Westminster; and there the new industry was left in the hands of chemists, who, however competent they might have been in their legitimate profession, were void of that mechanical knowledge and skill so essential to their task. Consequently numerous experiments were made, at the expense of a large portion of the capital invested; and the shareholders, who had hitherto shown such extraordinary patience so long as the enterprise was only in project, now, when they saw so much money sacrificed, and so little done towards commercially realising their hopes and expectations, began to lose heart.

At this period, when the practical application of gas appeared doubtful, the company had the good fortune to engage Clegg as their engineer. This gentleman had already acquired considerable experience in erecting gas-works. His genius rendered him capable of surmounting the greatest difficulties he encountered, and he may with justice be said to have established the manufacture of gas: inasmuch as to Clegg we are indebted for the system of wet-lime purification; the hydraulic main, with its contrivance of dip-pipes for isolating the retorts; the governor or regulator for adjusting the delivery of gas into the mains; to which must be added the gas-meter in its earliest and most novel form, which was afterwards perfected by John Malam, aided by Samuel Crosley, and will claim our attention at a future page.

These are the principal parts of the mechanism of gas apparatus introduced by Clegg, and which have become essential parts of gas manufacture, while other contrivances of perhaps equal ingenuity and merit have not been successful. Among these are the rotating, and web retort, the inferential dry gas-meter, the collapsing gas-holder, and an apparatus for the decomposition of oil tar. A review of his various inventions undoubtedly places the name of Clegg in the very foremost rank of those who have advanced the practice and science of gas-lighting.

In December, 1813, Westminster Bridge was first lighted by gas; and in the following year the old oil-lamps were removed from the streets of St. Margaret's parish, Westminster, and gas-lights put in their place; this being the first parish that applied for a contract to have the streets thus lighted.

In the year 1814, when the allied sovereigns visited this country, and a general illumination took place in commemoration of the peace of Europe, the new light was brought into requisition, and exhibited to thousands of admiring spectators in illuminating a magnificent pagoda erected in St. James's Park. This building was by a simple contrivance instantaneously lighted, when ten thousand lights burst forth, forming an immense and brilliant fountain of fire. The following year Guildhall was lighted with gas; and on this occasion the public papers teemed with extravagant praises of the new light. Its mild splendour was described as "shedding a brightness clear as summer's noon, but undazzling and soft as moonlight, altogether forming a magnificent combination worthy the inauguration of the presiding citizen of the great city."

After the founders of the gas company had striven against and overcome the prejudices of public opinion—had expended considerable sums in experiments, and incurred great losses in carrying the new art to a successful issue—and gas-lighting had become established—this accomplished, and the trade being open to all, there arose rival companies in the metropolis, namely the City of London, the South London, or Phœnix, and the Imperial. Other companies were also established, in Glasgow, Edinburgh, Manchester, Bristol, Bath, Leeds, Chester, Cheltenham, Macclesfield, Exeter, Birmingham, Rochester; and such was the rapid progress of gas-lighting from 1814, that all the works in these as in many other towns were in operation in the year 1819.

In 1815 John Taylor obtained a patent for producing gas from "any kind of animal, vegetable, or mineral oil, fat, bitumen, or resin, which is, or can be, rendered fluid by heat or otherwise," and in order to purify this gas it was caused to pass through lime and water, or through dilute acids.

This patent was afterwards acquired by a few influential gentlemen when it was practically applied at Apothecaries' Hall and other places about 1819. Oil gas then began to attract the attention of some scientific men, who reported so favourably concerning it, as to induce a few companies which were projected to light some towns in the kingdom, to construct their works for its manufacture. One great inducement for such a recommendation was the comparatively small capital stated to be required for the plant of the works and mains, on account of the alleged great superiority of oil gas, as it was pretended that it yielded three, and even four, times the light of coal gas; and consequently the works and mains for an oil gas-works would be diminished in a corresponding proportion.

In 1823, when the north side of London was supplied by no less than four gas companies, another, the London and Westminster Oil Gas Company, was projected. This naturally was the cause of considerable alarm to the coal gas companies, who resolved to oppose their rival. A petition was consequently presented to the House of Commons, in which was described the rise and progress of the Chartered Company, among other points it alluded to the "prejudices and difficulties they had overcome, the sacrifices they had made, together with the hazard and expense they had incurred in the course of their operations, from which the public had in many respects derived great advantages." The company also particularly noticed the great loss and injury sustained by them, in being compelled by Act of Parliament to give up a district which produced a rental of £15,000 a year, in consequence of a report made by the Inspector of Gas-works, Sir W. Congreve, to the Secretary of State; by which fact at that early period the evils of competition were clearly demonstrated.

An investigation was entered into by a committee of the House of Commons, which extended over several months, when, after several scientific and practical witnesses had been heard on both sides, the inquiry terminated against the promoters of the Oil Gas Company, at an expense of something like £30,000 to the different coal gas companies of the metropolis. It should be stated that among the witnesses examined were gentlemen who had the management of oil gas-works, and who described the loss arising from them, and the necessity for employing coal gas in order to render their operations remunerative.

We learn that in 1819 David Gordon obtained a patent for compressing gas into suitable vessels fitted with proper valves, and capable of being carried about, so as to render it portable. This contrivance, which can scarcely be called an invention, as it had been practised by Murdoch many years before, led to the formation of the "London Portable Gas Company," which had their works established in the neighbourhood of Clerkenwell, from where they issued the gas compressed to thirty atmospheres, supplied in copper receivers of the capacity of about two cubic feet each. However, after carrying on business some time, it was found that the scheme would not answer, and the company was ultimately broken up. About the same time Professor Daniell was engaged in an unsuccessful attempt to make gas from resin. It is said that his apparatus was highly ingenious, but on trial, the project was soon abandoned, from its inability to compete with coal gas. The Act for lighting Bristol with oil gas was obtained as late as 1823, in spite of the warnings of several eminent engineers that the project would prove unsuccessful. The truth of these warnings was amply confirmed in the course of a few years.

Paris was first lighted by gas in 1820, and although previously strong prejudices existed against the project, yet, when accomplished, it produced a corresponding enthusiasm; and, to give an instance, a French author of the period, writing to a friend, describing the new light, said "where gas-light exists there is no night; where gas-light is there is continuous day." He also mentioned, in the most glowing terms, the transcendent beauty of the ladies as seen thereby.

Gas companies increased very rapidly, but generally with very small capitals, as in towns of 20,000 or 25,000 inhabitants in some instances, the capital did not exceed £5,000; and in 1829 there were no less than 200 gas companies established for lighting various towns in the United Kingdom.

The Imperial Continental and the European Gas Companies were established about 1825, and instrumental in establishing the former was Sir W. Congreve, the inspector of gas-works.

We now come to the period in the history of gas-lighting when a ruinous system of rivalry existed among companies; and when we look back and consider the facts, we are at a loss to assign any reason for such extraordinary proceedings; inasmuch as for many years there were but few companies that paid their expenses, whilst many were on the brink of ruin, yet this did not deter the formation of other similar enterprises. Taking as example the metropolis, the Imperial Company from the date of its formation for years never realised one shilling profit. The same observations apply to the Phœnix and the City of London, which were all in operation before 1819, and only one, the Chartered, earned very moderate profits. Still, in the face of these facts, the London, Equitable, and South Metropolitan Companies were all established about the same period to oppose existing enterprises, with, during many years, the worst results; inasmuch as the two first-mentioned undertakings, struggled for nearly twenty years without earning a dividend, and only at the end of seven years after they commenced operations, was the South Metropolitan remunerative.

The effects of that competition are almost incredible, as within our knowledge, in districts where there were three contending companies, the unscrupulous gas consumers did as they pleased. Thus when the supply was discontinued on account of non-payment, a mere nominal deposit was sufficient to induce another company to take the lighting, until eventually the "services" of the three companies were attached to the premises; when in some cases the consumer took advantage of this, and the secrecy observed by the rival enterprises, and had his premises lighted for years without paying either company.

At that time concessions of every kind were made to consumers in order to obtain their custom, sometimes by permitting one or more lights to be supplied without charge; or alterations in the fittings would be done gratuitously by the company; and often gas was supplied at one-third of the proper scale. Frequently a meter would be placed on premises, and a fortnight after a rival company would supply them by contract. In short, such was the spirit of opposition, that it reached to the point of personal animosity among the directors and officers of the rival undertakings.

Nor was this ruinous system the only source of loss to a company, but in addition to this, in consequence of the hurried manner in which the mains were generally laid, together with the alterations in old and construction of new sewers, and the frequent changes of services, escapes of considerable importance existed in several parts of London. And wherever there was opposition, the officers of each company laid the responsibility on its rivals, and often only when the parish authorities insisted, and made their complaints to the boards of the respective companies, were any attempts made to remedy the evil. But more surprising still was the fact, that in the event of a leaking being discovered on the main of a company, at times, it was attributed to wilful damage on the part of the workmen of the rival undertakings.

For years that stupid competition existed, which could have been easily avoided by some show of conceding on the part of the directors of either of the companies; and only to a misguided obstinacy by those in power, was due the loss arising from such ruinous proceedings. Opposition commenced from the first establishment of gasworks, sometimes between coal gas companies, in other instances between oil and coal gas. The latter, however, terminated before 1829. Fortunately in the United Kingdom this competition is very properly at an end, with the best results both to the public at large and gas undertakings; and wherever it exists, it is to the interest of all the parties concerned to bring about a reconciliation, and either amalgamate the opposing companies, or to let each possess and supply a separate district.

During the last fifteen years gas has become very extensively applied for warming dwellings and other localities, for heating baths, for cooking and numerous other domestic purposes, as well as to obtain motive power, all of which will have our attention so far as space permits. We will also endeavour to present to the reader all the most improved methods of manufacturing gas, with a description of the apparatus employed, and the most approved means of distributing it.

CHAPTER II.

THE CHEMISTRY OF GAS-LIGHTING.

Chemistry, Organic and Inorganic—The Elements of Chemistry—Compounds—Analysis—Decomposition—Gases—Tests—Oxygen—Hydrogen—Nitrogen—Carbon—Sulphur—Affinity—Symbols—Combining Proportions—Formula.

THE daily operations of the gas engineer or manager are so intimately associated with chemistry as to render a partial knowledge of that science—at least so far as regards the gases he has to treat with—of the first necessity. It is therefore intended to give a very brief outline of it, which we trust may engage some of our readers to enter into the study of the subject.

Chemistry is the science which teaches us the composition of all materials, and the laws regulating the combination of the elements of which they are composed. For the purposes of study it is usually divided into two branches, viz. organic and inorganic chemistry.

The first branch relates to every living object, from the largest being to the smallest animalcule; likewise all vegetable life, from the most stupendous tree to the minutest trace of vegetation. These, having organs of vitality, are with much propriety called organic bodies. The other class, which consists of inanimate objects, which neither live nor die, having no such organs of vitality, are called inorganic bodies.

All organic and inorganic bodies, constituting everything accessible to man, consist of, or are composed of, about sixty-four simple substances, called *elements*, which are so named because they cannot by any known means be decomposed, that is, resolved into simpler kinds of matter. These elements combine with each other in certain relative proportions, and form substances called *compounds*.

Of the elements, about fifty belong to the class of metals, as iron, gold, copper, lead, tin, &c., the other fourteen, more or less, are of very dissimilar natures; but those elements which immediately interest the gas manufacturer are few in number, being only five, viz. oxygen, hydrogen, nitrogen, carbon, and sulphur, which are of the greatest importance on account of their vast abundance in nature, because one or more of them exist in almost every substance or compound, whilst they all enter into the formation of coal, and therefore influence the manufacture, distribution, and combustion of gas.

To render the combination of the elements and the formation of the compounds intelligible, we may compare the chemistry of our globe to a language having about sixty-four letters, each of which letters may be considered to represent an element.

A letter in a language resembles an element in chemistry, inasmuch as neither can be reduced or decomposed into anything less than itself.

Letters combine in various manners and ways to form words; so the elements combine in a similar manner to form compounds.

The nature of the word is dependent on the letters composing it, and on their disposition; so in chemistry the nature of the compound depends on the composition and disposition of its elements.

And to continue the comparison, the five elements named may be compared to the vowels, without which no word can be formed; so few compounds exist without the presence of one or more of these elements.

Hence these letters in unison form the words which combined constitute a language; and the elements form the compounds which comprise the earth and all that is on its surface.

The elements which comprise a substance or compound are discovered by employing means to separate them from each other, which process is called decomposition, and is the basis of what is termed *analysis*. This decomposition is very frequently effected by the application of heat; thus the black oxide of manganese, a natural compound, an union of two elements, the one a metal called manganese and the other oxygen, when submitted to a red heat in a retort is decomposed, part of the oxygen being separated and expelled as gas, whilst a lower oxide of manganese is left in the retort. Here it is obvious that the oxygen now existing as gas must have formed part of the solid previously to the compound being exposed to the heat, and if the solid be weighed before and after the process, the loss of weight by the separation of the oxygen will be found to be considerable.

Again, with limestone, a compound of three elements, carbon, oxygen, and calcium, or lime—some descriptions of which have almost a flinty appearance—on being exposed for a time to a great heat, as when intended for building purposes, loses about from 35 to 40 per cent. of its weight, which is driven off as a compound gas, consisting of carbon and oxygen, and called carbonic acid. The residue, deprived of these, is entirely altered in its nature, being no longer the hard rock, but lime, which crumbles to dust on exposure to the atmosphere. Hence the carbon and oxygen, which now assume the gaseous state, must previously have existed as a solid composing part of the limestone.

The decomposition of coal by heat, as in the manufacture of coal gas, is entirely a chemical operation. Coal, as already observed, contains all the five elements named, and the result of the decomposition is that the greatest portion of the hydrogen and the volatile carbon are expelled as gas; a portion of the oxygen and hydrogen form water; the nitrogen, with a portion of hydrogen, constitutes ammonia; a portion of the sulphur and hydrogen comprise the impurity, sulphuretted hydrogen; another portion of sulphur unites with carbon, and produces the troublesome impurity called bisulphide of carbon, or sulphur compounds in "other forms." The tar is a compound of several of these elements; and the coke left in the retort is fixed carbon, intermixed with earthy substances and a minute portion of sulphur.

Water is composed, *by weight*, of one of hydrogen and eight of oxygen; by means of voltaic electricity, it may be decomposed into its two component gases, the one being liberated at what is called the positive pole, and the other at the negative pole of the battery. These gases, when collected, are found to be in the exact proportion, *by volume*, of two of hydrogen to one of oxygen. If we, therefore, take into consideration their respective weight and volume, oxygen is found to be sixteen times heavier than hydrogen.

Now, if the gases produced from the decomposition of water be placed in a strong vessel, say a soda-water bottle, so as to fill it, and in the same proportions that they were liberated, on a lighted match being applied to the mouth of the bottle, an explosion with a loud report takes place; the two gases ignite, and at the same moment re-unite, forming water, which bedews the side of the bottle.

Thus we find by the first experiment that water is resolved into the two gases of which it is composed; and by the second these again are converted into the liquid form—striking illustrations of the truth of chemistry. This is but one of the many instances where a substance can be decomposed and afterwards again caused to assume its former state.

From the foregoing illustrations it is manifest that oxygen enters into the composition of solids, as when it comprises part of the oxide of manganese, and limestone; that it is a constituent part of water; and that when separated from its compounds it exists only as gas. Most elements enter into the three different states of aggregation —the solid, the liquid, and the gaseous state.

Gases are permanently elastic fluids; vapour, or steam, convey to us the idea of the bulk of gas. But these by a diminution of temperature condense, and become liquid; whereas gases, under all ordinary circumstances, are permanent in their state. Smoke issuing from a chimney or elsewhere is a mixture of several gases combined with vapour and small solid particles of carbon, called soot.

Gases are of various kinds, and very dissimilar in their properties; and, although generally invisible, the chemist's art teaches him to distinguish the one from the other with the greatest certainty, so as to render them as palpable to the mind, if not to the eye, as the different solids which surround him. Each description of gas has some distinguishing characteristic, such as weight, odour, colour, power of extinguishing fire, or of supporting its combustion, or the manner it acts on particular substances, called tests, signifying testimony.

These tests are substances which are known to change in their appearance and nature, in a peculiar and characteristic manner, when exposed to the action of certain gases or liquids. Thus an impurity in coal gas called sulphuretted hydrogen—a compound of sulphur and hydrogen —when allowed to act upon a piece of paper saturated with the acetate, or sugar, of lead, the paper immediately becomes blackened, and ultimately assumes a metallic appearance, occasioned by the sulphur of the sulphuretted hydrogen, entering into combination with the lead, which was previously in union with the acetic acid.

Hence the acetate of lead is one of the substances acted upon by the impurity in a perfectly understood manner, and is, therefore, selected as a test for sulphuretted hydrogen. A very general test for discovering the presence of acids or alkalies is litmus paper; which in its natural state is blue, but when treated with the least quantity of a weak vegetable acid, such as vinegar, becomes red, and this when acted upon by an alkali resumes its former blue colour. The test generally used to detect the presence of ammonia is turmeric paper, which is of a peculiar yellow colour, but becomes brown when submitted to the action of that compound. There are, however, several kinds of tests; amongst them is the method of ascertaining the presence of certain gases by means of absorbents, which cause them to become fixed, and to assume a liquid or solid state.

With this introduction we will consider the properties of the five elements named, and afterwards their combination in forming coal gas and its impurities.

Oxygen.—This is by far the most abundant element in nature, and in its gaseous state forms more than one-fifth part of the atmosphere by which our earth is surrounded. As a liquid, in union with hydrogen, it constitutes by weight eight-ninths of all water; as a solid, it is a portion of innumerable organic and inorganic bodies; and is estimated to form about one-third of the mineral crust of our globe.

When free, that is when uncombined with any other element, oxygen exists only as a gas, and this occurs either when it is emitted by the leaves of plants or vegetation, or when by the agency of man it is separated from other elements with which it is in combination, and forming a certain compound or substance. The element in question is the support of all animal life and combustion, and possesses very peculiar properties; for instance, a body which burns in air, when it is immersed in oxygen gas, burns with vastly increased splendour; thus the wick of a recently extinguished candle, having the least part red-hot, when inserted into a jar of this gas, is immediately re-lighted; and a piece of charcoal with the smallest point ignited when so treated burns with great brilliancy.

Oxygen gas is inodorous, colourless, and rather heavier than air; and it may be termed the aërial food of animal life, for at each respiration a portion of it intermixed with nitrogen, composing what we term "air," is received into the lungs, which after acting on the blood is ejected, being partly converted into the poisonous compound, carbonic acid gas.

It is almost unnecessary to observe that oxygen or any other element, can only be obtained from a compound which possesses it, and by adopting means to separate it from that compound. Thus chlorate of potash, red oxide of mercury, and black oxide of manganese, in common with many other substances, contain a large quantity of oxygen, which is easily separated as a gas, by means of heat.

For example, red oxide of mercury is a mixture of oxygen and quicksilver, in the form of a red powder; and if a few grains of this be placed in a test-tube and held over the flame of a lamp or gas-burner, the heat expels the oxygen as a colourless gas, leaving the quicksilver in its fluid state. This is decomposition, and was the means first employed to obtain oxygen by its discoverer.

But a more economical manner of obtaining this gas is by taking a quantity of black oxide of manganese, of which one pound will evolve about 1,400 cubic inches of oxygen, placing it in a cast-iron retort, and distilling similarly to the distillation of coal for the production of gas; the oxygen gas can be collected in a gas-holder or other vessel for use when required. One ounce of chlorate of potash, by careful application of heat, will afford about two gallons of oxygen.

Hydrogen.—This element is also very abundant, but does not exist free or uncombined in nature. It is a constituent of all animal and vegetable substances, forming by weight one-ninth part of water, and is a portion of most combustible bodies. Hydrogen gas is colourless and tasteless, and when quite pure is without odour; it is inflammable when issuing from an orifice and intermixing with the atmosphere, burning with a faint violet colour, giving great heat, but very little light.

This gas is the lightest substance in nature, being a little more than one-fifteenth part of the weight of air. It is an invariable component of coal gas, both in a free state and in combination with carbon, such as light carburetted hydrogen, or marsh gas, olefiant gas, or other vapours of carbon combined with hydrogen, and called hydro-carbons.

Hydrogen for perfect combustion requires eight times its weight or half its volume of oxygen, as already demonstrated by experiment, the result of the combustion being water. In every case wherever artificial light is obtained by burning oil, tallow, gas, petroleum, or other analogous substances, this production of water is continually taking place, arising from the hydrogen composing part of the material consumed, uniting with the oxygen of the atmosphere; and the water is distributed as vapour in the locality wherever it is produced, unless means be employed to condense and collect it. Whenever gas-lights are burned in a shop or in an apartment without proper ventilation, the vapours are condensed on the cold glass window, an inconvenience which is familiar to all; or a bottle of cold water brought into a room where several lights are burning is speedily covered with a dew, caused by the condensation of the vapours by the cold water.

A simple way to obtain hydrogen gas is by passing a slow current of steam through a small iron tube of about an inch in diameter, loosely filled with iron borings; the tube with its contents is placed across a suitable furnace, or blacksmith's forge, and heated to bright redness; when the steam on passing, is decomposed into the two elements of water, namely, oxygen and hydrogen; the oxygen combining with the iron forming the oxide of iron, while the hydrogen gas is set free and can be collected in a holder.

Another convenient method is by putting a few pieces of zinc into a glass vessel, and pouring on them a mixture of one part of sulphuric acid and four or five parts of water; the gas then rises in bubbles. In this experiment the zinc unites with the oxygen of the water, and subsequently with the sulphuric acid, and the hydrogen is liberated.

Thus hydrogen exists in solids forming part of animal and vegetable substances; in liquids as a component of water, and can be obtained in its gaseous state by decomposing its compounds.

Nitrogen.—This element is so called from its being the basis of nitric acid and nitre, and is sometimes named azote, from its incapability of supporting life.

Nitrogen constitutes nearly four-fifths of the air we breathe, and serves to temper the effects of the oxygen, which, if breathed alone, or even when in moderate excess of the proportion stated, would be too energetic. It is also a component of all animal tissues, muscles, &c.

Nitrogen gas is slightly lighter than air. It has neither colour, taste, nor smell; it does not support combustion nor respiration; and is characterized by its negative properties rather than by possessing any inherent poisonous qualities, such as are peculiar to carbonic oxide, or carbonic acid, as hereafter mentioned. Nitrogen is of interest to the gas manufacturer on account of its influence on the combustion of gas, also because it is one of the components of the alkali ammonia, which is always generated during the distillation of coal in making gas.

In order to demonstrate the composition of atmospheric air, let us take a cup containing a small piece of phosphorus, which is placed in a dish of water. The phosphorus is then ignited, and the cup covered by a bell-glass or a glass shade, the mouth of which is immersed in the water. The phosphorus, in burning, combines with the oxygen of the air enclosed in the glass, producing phosphoric acid, and when all the oxygen is absorbed by the phosphorus, or has entered into the fresh combination, the phosphorus ceases to burn in the absence of oxygen; the water in the meantime, by the removal of the volume of the oxygen, ascends in the glass. The gas underneath the bell after the operation, is nearly pure nitrogen, and the bulk will be found to be diminished about one-fifth; this decrease of volume being due to the absence of the oxygen which formerly existed in a gaseous state and has entered into the composition of the flakes of phosphoric acid; thus again illustrating how a gas can enter into the formation of a solid.

Carbon.—This is likewise one of the most abundant elements, and is extensively distributed in nature as a constituent of all animal and vegetable bodies. It exists in the mineral kingdom in various forms—very largely in the state of coal. It also enters into the composition of some earthy bodies, as, united with lime, it forms marble, chalk, and limestone. The diamond, although unlike any of the substances named, is pure carbon, and is about three and a half times heavier than water.

The carbonaceous incrustation in retorts, the soot produced by the imperfect combustion of oil or gas, lampblack, and charcoal, are all carbon, more or less impure.

Under ordinary temperatures, carbon has no affinity for oxygen, nor is carbon affected by heat, unless oxygen be present. Thus the diamond remains unaltered in the hottest furnace if that body is excluded; but if oxygen be present it will combine with it to form carbonic acid, at a comparatively low temperature.

The combustion of carbon in air, or oxygen, produces light, more or less brilliant, according to the degree of heat to which it is raised.

Carbon is never found alone in the gaseous state, but several gases have the power of combining with it and conferring on it that property; but as soon as the combinations are destroyed by the abstraction of the other gaseous body the carbon again becomes solid—a most important property, which requires especial attention in connection with the combustion of gas.

Sulphur.—This exists in large quantities in nature, forming part of the ores of copper, lead, mercury, silver, and other metals. It also issues from volcanoes in the form of gases in great abundance, and its solid state is well known under the name of brimstone. It is found in combination with coal, as indicated by the bright metallic laminæ which intersect it; these being chiefly a compound of sulphur and iron. Coke, even after having been submitted to a very protracted and high heat, still contains a portion of sulphur, giving rise to the noxious odour occasioned by burning it in confined places. A highly volatile compound of sulphur and carbon, namely, the bisulphide of carbon, is produced in the distillation of coal, by the combination of a certain amount of sulphur with carbon.

The peculiar, disagreeable odours of many of the compounds of sulphur are familiar to all, and are the most troublesome of all the impurities of coal gas, the economical removal of which has until very recently defied the chemist's skill.

COMBINATION OF THE ELEMENTS.

Having briefly given a description of the various elements in chemistry which immediately interest the gas manufacturer, we will now enter on their combinations to form coal gas, its impurities, and the results of its combustion.

By a law of nature all elements have, in their most minute particles or atoms, an innate attraction for certain others, with which they combine and form compounds. This by chemists is called affinity, and by this law of affinity, oxygen and hydrogen combine and form water—thus by the intervention of the electric spark, or fire, these gases unite to compose that liquid. By affinity carbon combines with oxygen, producing carbonic oxide and carbonic acid. As already observed, sulphur combines with hydrogen, and the result is sulphuretted hydrogen. Nitrogen combines with hydrogen, and ammonia is produced. And by the action of this affinity all the various compounds, or substances in nature, are formed.

For the sake of brevity and general elucidation, chemists have devised a very simple means of describing compounds, and at the same time to express their constituent and quantitive parts. For this purpose, instead of writing or naming the elements in full, abbreviations are employed, which are frequently the capital initial letter of the element to be expressed; or when there are two or more with the same initial, then a second small letter is added to make the requisite distinction. In those under notice the initial only is employed, thus—oxygen is expressed, O; hydrogen, H; nitrogen, N; carbon, C; sulphur, S; which are called the *symbols* of their respective elements. Of course all the other elements have their corresponding symbols.

Whenever elements combine with each other it is only in a particular and definite manner, which is called their combining quantities or proportions, and this occurs by weight and by volume, which bear a direct relation to each other. Those under consideration combine by weight in the following proportions, or their multiples:—

Hydrogen	1
Oxygen	16
Carbon	12
Sulphur	32
Nitrogen	14

These numbers are called the equivalents of their respective elements.

When gases combine it is always by measures, which bear a simple relation to each other in the following proportions: thus, hydrogen combines with oxygen in the proportion of two volumes or bulks of the former with one volume of the latter gas; hydrogen and sulphur in like proportions; nitrogen and hydrogen in the proportion of one to three.

The chemical expression, or, as termed, formula, of the composition of water is $H_2 O$, signifying two atoms or equivalents of H (hydrogen) combined with an atom of O (oxygen). As already stated, hydrogen constitutes by weight one-ninth part of water, and by volume two-thirds; whilst oxygen by weight constitutes eight-ninths, and by volume one-third; giving a simple illustration of the combining proportions by weight and volume.

In order to give examples of the combination of the elements to form compounds and the formula employed:—One equivalent or atom of carbon combined with an atom of oxygen form carbonic oxide, expressed by the formula $C O$. One atom of carbon with two of oxygen, expressed $C O_2$, constitute carbonic acid. One equivalent or atom of nitrogen with three atoms of hydrogen, formula $N H_3$, produce ammonia. By these means the various compounds of gases are formed and expressed.

CHAPTER III.

THE COMPOSITION OF COAL GAS.

Constituents of Crude Gas—Olefiant Gas—Acetylene—Benzole—Various Hydro-carbons—The Diluents—Light Carburetted Hydrogen—Carbonic Oxide—Impurities—Ammonia—Sulphuretted Hydrogen—Bisulphide of Carbon—Other Carbo-sulphur Compounds—Composition of London Gas.

As already observed, gases are permanent elastic fluids; but coal gas differs in this respect, inasmuch as it is a compound of permanent gases intermixed with hydro-carbon vapours, or compounds of hydrogen, with the vapours of carbon in various proportions; which are capable of being condensed by diminished temperature, or absorbed by chlorine, bromine, sulphuric acid, and other substances.

Chemists have defined crude coal gas to consist of three constituents, namely, illuminants, diluents, and impurities. The illuminants are certain condensable hydrocarbons known as olefiant gas, acetylene, benzole, propylene, butylene, naphthaline, and other compounds of carbon and hydrogen.

The diluents are marsh gas, hydrogen, and carbonic oxide. The impurities consist of sulphuretted hydrogen, ammonia, carbonic acid, bisulphide of carbon, and other carbo-sulphur compounds; and, as shown hereafter, small quantities of aqueous vapour, oxygen, and nitrogen generally exist in gas.

The various methods of analyzing gas, in order to determine the presence of these compounds, is beyond the object of this work, although a passing reference is made to them hereafter. We will, therefore, confine our observations only to those points which are of the most interest to the practical man.

THE ILLUMINANTS.

Olefiant gas, or oil-making gas, is so named on account of its forming an oil when combined with chlorine or bromine, and is called the oil of the Dutch chemists, as it was first produced by the members of a scientific association in Holland. Iodine also absorbs olefiant gas abundantly, and forms a white crystalline substance which melts at 180°, and may be sublimed if air be not present. Olefiant gas, containing double as much carbon as the light carburetted hydrogen, burns with much greater brilliancy, and gives out a very superior light. Its density is ·981, and the weight of 100 cubic inches 30·57 grains.

Olefiant gas when pure is colourless, its odour is very slightly ethereal, it is sparingly absorbed by water, and burns with a brilliant white flame producing much smoke. When mixed with twice its volume of chlorine and set on fire in a tall narrow jar a brilliant flame descends rapidly, muriatic acid being formed, and carbon smelling strongly of naphthaline is separated.

This gas may be obtained by mixing alcohol with five or six times its weight of sulphuric acid in a glass retort, when, by the gentle application of heat, the gas distils over, which may be afterwards purified from carbonic acid by agitation with a solution of caustic potash.

Olefiant gas is combustible and explosive, under similar circumstances to light carburetted hydrogen, requiring, however, two volumes more oxygen, and is decomposed by passing it through a tube heated to bright redness, when a deposit of carbon takes place, and the gas becomes converted into light carburetted hydrogen. If the operation be performed with increased heat, the whole of the carbon is deposited, leaving the hydrogen free. This illustrates very forcibly the deterioration of coal gas by the deposit of carbon in the retorts, and to which the attention of the reader is especially directed.

Acetylene.—According to Dr. Frankland this is a colourless and transparent gas, having a peculiar and rather unpleasant odour; its specific gravity is slightly less than that of air, being ·920, or just 13 times heavier than hydrogen; it is tolerably soluble in water, and burns with an intensely luminous flame. Acetylene, when added to chlorine, explodes by the action of diffused daylight even, but especially of the diffused electric light. This explosion is attended with a very slight report, but with the evolution of a large quantity of carbonaceous smoke. If the experiment is reversed, and chlorine added to the acetylene, then the explosion takes place immediately, even in perfect darkness.

Acetylene is a constituent of coal gas, and is probably never absent from that gas. It possesses the peculiarity of producing a red precipitate when brought into contact with subchloride of copper, forming acetylide of copper. This acetylene may be produced by a variety of processes. The one which, perhaps, most interests us, as being that from which possibly the acetylene in coal gas is derived, consists in applying a very high degree of heat to marsh gas. Marsh gas, if heated much higher than when it is ignited in atmospheric air, is transformed into acetylene. That it does not suffer this transformation when burnt in atmospheric air we know from the lightless flame which it gives. Acetylene is an illuminant of a very high power, and it is not improbable that when atmospheric air is previously heated for the supply of the marsh-gas flame acetylene is produced, which forms the illuminating ingredient in that flame under such circumstances.

The next illuminant, which also belongs to a different family, is benzole. This is contained in coal tar, also in coal naphtha, which is distilled from coal tar. It is a limpid, colourless liquid, which refracts light strongly, solidifies at the freezing point of water, and boils at 177° Fah. A large quantity of this vapour can, therefore, be taken up by the diluents in coal gas, as when hydrogen gas is passed through a flask containing this liquid.

The hydro-carbons existing in coal gas, among which are butylene, propylene, and naphthaline, are classified by chemists into no less than twenty-two different kinds, which vary respectively in the quantity of the two elements entering into their formation. Further reference to them is not necessary, as it requires a high degree of skill to manipulate with them.

THE DILUENTS.

Light carburetted hydrogen, or marsh gas, is a compound of carbon and hydrogen, in the proportion of one atom of the former to four atoms of the latter, its chemical formula being $C\,H_4$. This compound constitutes the inflammable fire-damp of coal-mines, where it is generated spontaneously; it also proceeds abundantly from the decomposition of vegetable substances, and is one of the products of the distillation of coal.

This gas is colourless, nearly inodorous, and does not affect vegetable colours, and, like hydrogen, is permanently gaseous under intense cold or pressure. It is highly combustible in oxygen or air, and explosive to a violent degree, if mixed with either of these in the due proportion necessary to convert all the hydrogen into water and the carbon into carbonic acid. However, as the oxygen exceeds or falls short of that quantity, so is the explosive power decreased.

Marsh gas by weight contains 12 parts of carbon and 4 parts of hydrogen.

Its density is ·559, the weight of 100 cubic inches being 17·41 grains.

When marsh gas is burned in the air, if allowed to issue as a large thick flame, considerable light is obtained. It is possible, however, to burn it without any appreciable light, by causing it to issue under great pressure from very minute orifices. However, this peculiarity of burning, with or without the emission of light, according to the circumstances attending the combustion, exists with all the gaseous compounds of carbon and hydrogen.

Pure carburetted hydrogen gas may be respired in small quantities with safety. In its natural forms of marsh gas and fire-damp it is generally contaminated with nitrogen and with a small proportion of carbonic acid gas. The unpleasant smell of common coal gas is due to impurities.

The properties of the diluent hydrogen have already been described. Another of these diluents, carbonic oxide, or the protoxide of carbon, consists of one atom of carbon and one of oxygen, and is prepared in the laboratory by passing carbonic acid over red-hot charcoal, by which half its oxygen is removed, when it becomes converted into carbonic oxide. This change explains the mode of its formation in the process of distilling coal for gas-making purposes.

Carbonic oxide is a colourless inodorous gas, contains half its volume of oxygen, is combustible, and burns with a beautiful blue flame, as may be observed on the top of a clear coke fire, the product of combustion being carbonic acid. This gas is extremely poisonous, even worse than carbonic acid, is colourless, and possesses very little odour. Indeed, if carbonic oxide be present to the extent of two per cent. in the atmosphere, it might prove fatal, and it is probably this that kills in the action of suffocation by the fumes of charcoal. The specific gravity of carbonic oxide is ·968, the weight of 100 cubic inches being 30 grains. This compound exists more or less in coal gas, but seldom exceeding ten per cent. by volume, and generally much less. It requires one volume of oxygen for combustion and is then converted into carbonic acid.

Carbonic oxide contributes to the heat of the flame, but only indirectly to the light. It is not considered an impurity in coal gas; although the fact of its giving off less heat than hydrogen, while it absorbs the same quantity of oxygen, and produces one volume of carbonic acid—a substance always very objectionable—undoubtedly renders it highly objectionable.

The Impurities

Sulphuretted hydrogen.—This is a colourless transparent gas, possessing a most disagreeable odour commonly compared with putrid eggs. Its specific gravity is slightly greater than that of atmospheric air. It is very poisonous, occasioning suffocating vapours like those arising from the burning of brimstone, and if breathed is injurious to life. One of its properties is that it discolours paints, as almost all paints contain carbonate of lead, which is acted upon in the same way as the test, acetate of lead, which is usually employed to detect the presence of the impurity in question. Sulphuretted hydrogen tarnishes metals, changes the colour of most furniture hangings; and when coal gas possessing it is burned, the sulphur combines with the oxygen of the atmosphere, and forms sulphurous acid. Therefore, with all the various evils enumerated, it is of the utmost importance that gas should be entirely free from this impurity, and any company neglecting this, does a serious injury to their business, as well as occasioning considerable annoyance to their consumers.

Previously to purification, about eight feet of sulphuretted hydrogen exist in every thousand feet of gas obtained from Newcastle coal.

Sulphuretted hydrogen consists by weight of 1 part of hydrogen gas and 16 parts sulphur compound. By measure it contains two volumes of hydrogen combined with one volume of the vapour of sulphur, being condensed into the space of two volumes. Its specific gravity is 1·178, the weight of 100 cubic inches being 36·51 grains.

This impurity is formed by the combination of sulphur and hydrogen at a red heat. Coal of the best quality contains iron pyrites which intersect it in laminæ of bright metallic appearance, and when hydrogen comes in contact with this compound, at the temperature at which coal is generally carbonized, it takes from it a quantity of sulphur and becomes converted into sulphuretted hydrogen.

Ammonia.—This can be removed from gas with the greatest facility, and except in the smallest of works, should be a source of revenue to a gas company; ammonia is produced abundantly in nature from the decomposition of animal and vegetable substances, the gas is colourless and very pungent, acting strongly on the mucous membrane of the nose, the eyes, and throat.

This impurity is produced during the carbonization of coal, as already observed, by the combination of hydrogen with the nitrogen, which is contained in the coal, as in all organic substances, or substances of organic origin. The density of ammonia is ·589, the weight of 100 cubic inches being 18·26 grains. A great part of the ammonia is separated from gas by the condensing apparatus, combined with water, and called ammoniacal liquor. This liquor is the principal source from which the ammonia is procured; and numerous patents have been taken out at various times for improvements in the mode of treating it, in order to produce the sulphate, carbonate, muriate, and other salts of the compound.

Ammonia has strong alkaline properties, and its presence is detected by moistened turmeric paper, which, when exposed to the action of this gas, changes from its yellow colour, to a deep red or brown. It is also detected by reddened litmus paper, which changes to blue. But the most minute quantity that may be present, is ascertained by filling a glass flask with the gas to be examined, and inserting into it a glass rod previously dipped into muriatic acid, when, if ammonia be present, a white cloud of the muriate of ammonia is formed in the flask. The means of manufacturing the impurity and residual in question will be the subject of another chapter.

Ammonia in small quantities is not injurious to health, but it acts on some of the metals, as brass and copper which compose the fittings and meters, and is so far an impurity. Against this, it converts any sulphuric acid formed during combustion, into sulphate of ammonia; therefore in this respect a very small quantity in the gas is beneficial, and must be considered so until means are devised for freeing gas from all its sulphur compounds. An eminent chemist considers that a limited quantity of ammonia in combination with the gas prevents the deposit of naphthaline in the pipes.

Water absorbs about 700 times its own volume of ammoniacal gas, and this property is taken advantage of in order to eliminate it from the gas. Ammonia is a gaseous body, and that which is usually called so in the liquid state, is ammoniacal gas intermixed with water.

Carbonic acid is another impurity which is always generated in the process of manufacturing gas, because oxygen exists in all descriptions of coal. Part of this oxygen unites with the hydrogen present in the coal, with the production of water; the remainder combines with carbon and generates two distinct compounds, namely, carbonic acid, an impurity, and carbonic oxide, a diluent, as described. Carbonic acid contains the largest amount of oxygen that ever combines with carbon. It is perfectly colourless and transparent, and half as heavy again as atmospheric air. It is very poisonous, is incapable of combustion, or of supporting combustion; thus it is obvious that it is useless in gas. Carbonic acid is not, however, only useless, but is an exceedingly pernicious compound, acting in a marked manner, and deteriorating the illuminating power of the gas with which it is combined, as a mixture of only 1 per cent. of it with gas, reduces the illuminating power about 7 per cent.; and for this reason alone it is very desirable that this impurity should be eliminated.

Bisulphide of carbon is a compound of carbon and sulphur, and is formed wherever sulphur comes in contact with red-hot coke or charcoal; and as a portion of sulphur is always retained by the coke during its combustion to the last, it is evident that whenever a charge of coal is worked off, the longer the red-hot coke is left in the retort, the greater will be the quantity of the pernicious compound in question.

Bisulphide of carbon may be produced by heating some iron pyrites to redness in a close porcelain vessel with one-fifth their weight of well-burned and dry charcoal. It may be condensed as a colourless liquid having an acid taste and very offensive odour. It is a remarkable solvent for indiarubber, boils at 116° Fah., and vaporises with great facility.

Of the other compounds of sulphur and carbon in gas, little is understood at the present time.

By some engineers coal gas is considered to be sufficiently pure for commercial purposes when it indicates no traces of sulphuretted hydrogen, ammonia, or carbonic acid, when tested for these impurities by the ordinary means. However, of late years considerable importance has been attached to the presence of the bisulphide of carbon and other similar compounds as an impurity in coal gas. Hence, in all recent Acts of Parliament, the gas to be supplied by a company is defined to be of that quality that it shall not contain more than 20 or 25 grains of sulphur in any form, in the 100 cubic feet. But in order to show that an undue importance has been attached to this, we may state that on one occasion the late Dr. Letheby examined the gas of 24 towns in the United Kingdom, and in 17 of them the quantity of sulphur was less than 15 grains, while in 7 it was below 10 grains per 100 cubic feet. In the proper place we will again refer to this subject.

According to the late Dr. Letheby, the following is the average composition of London gas:—

	Common Gas (12-candle).	Cannel Gas (20-candle).
Hydrogen	46·0	27·7
Light carburetted hydrogen	39·5	50·0
Condensible hydro-carbons	3·8	13·0
Carbonic oxide	7·5	6·8
Carbonic acid	0·6	0·1
Aqueous vapour	2·0	2·0
Oxygen	0·1	0·0
Nitrogen	0·5	0.4
	100·0	100·0

The following table, extracted from a course of lectures by Dr. Frankland, gives the comparative illuminating power of the gas supplied to various cities and towns:—

European Capitals.

Name.	Authority.	Illuminating Power in standard Sperm Candles.
Berlin	Hofmann	15·5
Paris	Frémy	12·3
London	Letheby	12·1
Vienna	Redlenbacher	9·0
Edinburgh	Penny	28·0

British Cities and Towns.

Name.	Authority.	Illuminating Power in standard Sperm Candles.
Manchester	Leigh	22·0
Liverpool	King	22·0
Glasgow	Penny	28·0
Aberdeen	,,	35·0
Greenock	,,	28·5
Hawick	,,	30·0
Inverness	,,	25·0
Paisley	,,	30·3
Carlisle	,,	16·0
Birmingham	Frankland	15·0

CHAPTER IV.

COAL USED IN GAS-MAKING.

The Origin of Coal—Coal unknown to the Ancients—Its first Use in London—Proclamation forbidding it—The first Patent obtained in conjunction with Coal—The Composition of different Kinds—Lignates—Tables of Analyses, by Messrs. Lewis Thompson, Paterson, and Hislop—The Deterioration of Coal.

GAS for the purposes of lighting and heating, is generally obtained by the destructive distillation of coal, and according to the quality of the coal, and the manner the operations of carbonization and purification are conducted, so will be the quality and quantity of the gas.

The origin of coal is involved in some doubt, but the theory generally admitted by geologists is, that its formation was caused by the deposit of vegetable matter, which in the course of ages became converted into coal. Some eminent geologists suppose coal-beds to have been originally a kind of peat bog, or immense accumulations of masses of vegetable remains; and that subsequently the tracts of country where they existed, by some extensive convulsions of the earth, subsided below their former level, and were covered by various deposits. Others suppose that the trees of primeval forests were carried away by floods and rivers and deposited in immense lakes, where they were afterwards covered by mud, sand, argil, and such like substances, so constituting the covering strata. It is further conjectured that the vegetable remains, whether of trees, peat, moss, or other analogous substances, being buried, became after many ages converted into coal, while the deposits were converted into rock, shale, schist, and marl, which now intersect and cover the various strata of coal.

This assumption is formed from the fact that in all coal there are traces of vegetation, as ferns and even the trunks of trees, which are so positive in their form and appearance, often with the bark attached, as to leave no doubt of their origin. This was particularly the case with the Boghead Cannel, wherein the trunks and branches of trees were often found, the wood having the nature of that coal, while the bark resembled caking coal.

There are various other theories which have their supporters, and perhaps one of the most feasible is the supposition that coal was formerly a deposit of carbonaceous liquid similar to petroleum, and that by crystallisation this liquid became coal, such as we find it. Those of this opinion argue that the presence of trees and vegetation might have been accidental, or probably by the design of Providence, in order to assist in the crystallisation of the mass.

Coal appears to have been unknown to the ancients, indeed its use is comparatively of modern date, as the first colliery was opened in the high grounds in the neighbourhood of Newcastle-on-Tyne in the year 1238. About 1306 coal was employed in London by brewers, dyers, and other branches of industry which required large fires; but the smoke produced from them became so offensive to the resident nobility and gentry, that they remonstrated against its use, and in consequence, a royal proclamation was issued forbidding the use of coal as fuel in London. Some years afterwards, wood fuel becoming scarce, and the population and trade of the city increasing, prejudice gave way to utility, when the force of the proclamation diminished, and was eventually rescinded.

The use of coal became afterwards very general, but the extortion and abuse of the dealers therein was so excessive, that by Act of Common Council of the City of London, in 1665, each of the City trades companies was ordered to lay up large stores of coal in summer, which in winter was to be vended to the poor at as low a price as possible, consistent with avoiding any loss.

The first patent in conjunction with coal was granted in 1589, for the purpose of smelting iron therewith. Patents were subsequently obtained at various periods for obtaining oil, pitch, tar, and making charcoal (coke) from coal. In 1781 a patent was granted to the Earl of Dundonald for "a method of extracting or making tar, pitch, essential oils, volatile alkali, mineral acids, salts, and cinders from pit coals." By this it will be observed that although the patentee was well acquainted with most of the residuals to be derived from the distillation of coal, yet the most valuable constituent, the gas, was entirely lost sight of. A few years after this (1791) a patent was obtained for using an explosive mixture of inflammable air, combined with atmospheric air, to produce motive power—an invention which is only at the present day being carried practically into operation, and to which we shall have occasion to refer hereafter.

Coal by geologists is divided into four classes, namely, anthracite or glance coal; the semi-bituminous; the bituminous; and cannel or parrot coal. The anthracite consists almost entirely of fixed carbon. The semi-bituminous is allied to the former, and is found extensively in South Wales, and largely used for steam purposes. But neither this nor anthracite possesses any interest for the gas manufacturer.

Bituminous, or, more properly called, caking coal, as its name implies, in the act of combustion cakes together, and when in the retort after a time intumesces, becomes of a black doughy consistency, and, having yielded the larger portion of its gases, begins to agglomerate and increase in temperature until it becomes red hot, at which point the troublesome sulphur impurities are evolved.

The rich caking coals of Northumberland and Durham contain from 54 to 70 per cent. of fixed carbon, and from 4 to 5 per cent. of ash. Some qualities of these are unsuitable for household fires, on account of their tendency to cake together and obstruct the passage of the air. As a rule, these are very friable, and contain a large quantity of "slack," or small coal, which, although not adapted for the purpose mentioned, answer admirably alike for the production of gas and coke.

There are other classes of bituminous coal that do not cake, and are suitable for the manufacture of gas, although their coke, like that from cannel, retains the form it possessed prior to carbonization.

The other coal which is of important interest for the gas manufacturer, is the cannel or parrot coal, with which Scotland is particularly favoured. It is obtained to a limited extent in the North, also extensively in the Midland counties, of England. It is likewise found in North America, Belgium, and a few other places. A cannel identical in appearance with Boghead, and even of superior quality, is obtained in Australia.

Cannel is the richest of all coals for producing gas of high illuminating power. Its principal characteristics are, that it has a smooth compact appearance, and is duller in colour than other descriptions of coal; its fracture is flinty or conchoidal; it decrepitates when submitted to the heat of the retort, does not intumesce nor alter in form during the process of carbonization; and delivers its gas principally in a lateral direction, the coke resulting therefrom showing the laminæ whence the gas issued.

The coke from nearly every description of cannel retains the form and size of the coal previously to distillation. In its nature it is compact, and resembles charcoal, for which it is often substituted abroad. This coke is sometimes used as fuel for the furnaces; but very often an inferior description of coal is employed for the purpose, and the coke is sold. There is a description of Wigan, also Ramsay's cannel, which gives a coke very similar to the caking coal, enabling it to be used as fuel for the furnaces, and it is a more marketable commodity than that derived from other cannels.

There are other imperfect descriptions called brown coal, or lignite, which exist in many parts of the world, known also as bituminous wood, earthy lignite, and common lignite. Common lignite is of interest to the gas manufacturer, on account of its strong resemblance to coal, for which, by an inexperienced eye, it might readily be mistaken; when distilled it gives off an abundance of water, with a small yield of gas of low illuminating power, possessing a most offensive sulphurous odour, which lime purification does not remove. This material contains very little tar, and the residue left in the retorts is simply breeze in cubes. It is therefore useless for the manufacture of gas, and only serviceable for burning lime, bricks, and other out-door purposes.

All coals are composed nearly of the same ingredients, varying, however, considerably in their respective quantities, to illustrate which a table of the analysis of a few classes is subjoined:—

Locality, or Name of Coal.		Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ash.	Coke.
Welsh Coal.	Thomas's Merthyr . .	90·12	4·33	1·00	0·85	2·02	1·68	86·53
	Nixon's Merthyr . .	90·27	4·12	0·63	1·20	2·53	1·25	79·11
	Hill's Plymouth works	88 49	4·00	0·46	0·84	3·82	2 39	82·25
Newcastle Coal.	Newcastle Hartley .	81·81	5·50	1·28	1·69	2·58	7·14	64·61
	West Hartley Main . .	81·85	5·29	1·69	1·13	7·53	2·51	59·20
	Hastings Hartley .	82·24	5·42	1·61	1·35	6·44	2·94	35·60

The carbon in the composition of coal may either be fixed or volatile. By fixed carbon is understood that which does not volatilise when undergoing ordinary distillation, but remains in the retort as coke. The volatile carbon is that which passes off as gas, hydro-carbons, and tar.

The preceding table demonstrates this difference very forcibly, for in the Welsh coal upwards of 86 per cent. remain fixed as coke, and as a consequence this class, although admirably adapted for steam purposes, is useless for the manufacture of gas. According to the same table, the Hastings Hartley yields about 47 per cent. of volatile carbon, which renders it a good gas-producing agent. But this, on account of its volatility would be ill adapted for steam purposes, as without observing the greatest care a large portion of it would pass off as smoke.

The description of coal required to be carbonized by any company will of necessity be controlled by the quality of the gas stipulated to be supplied by them, whether according to arrangement with the local authorities, or under the authorisation of Parliament, or other circumstances. The facilities for disposing of the coke will also influence the choice of coal to be carbonized. The average defined quality for companies supplying gas to towns in England, Wales, and Ireland is that "5 feet of gas, when consumed with an argand burner, shall give the light of 14 candles, each consuming 120 grains of sperm per hour." But as argand burners are very variable in their construction and results, the Metropolitan Gas Referees, who to an extent regulate the quality of the gas supplied in London, have defined the dimensions of the test argand burner and chimney, which is described under the head of "Burners."

For the description of gas in question—that is 14-candle gas—the ordinary caking coal of Newcastle and other places, as well as some others which do not cake, are suitable. But caking coal is always preferable to the other, as all its little particles agglomerate and form coke; whereas the other, as observed, retains the form it possessed previous to carbonization, consequently the amount of breeze attending its use is always very considerable.

But in the event of a superior kind of gas to that mentioned being required, then a proportionate admixture of cannel with the common coal will be necessary. However, as will be found hereafter, the variable quality of cannels precludes any rule being laid down concerning the expense, or the quantity required to increase the illuminating power of gas to any given standard. In Scotland the gas supplied is of a very superior description to that furnished in the rest of the United Kingdom (if we except a few towns in the North), and averages about 25-candle illuminating power, which arises from the fact that cannel is very abundant in that country.

With the view of illustrating the composition of different kinds of coal, we have copied from Richards' "Treatise on Coal Gas" tables of analyses by Messrs. Lewis Thompson, Paterson, and Hislop, gentlemen who are well known for their accuracy in experimental investigations. Mr. Lewis Thompson's analyses refer principally to Newcastle coal, and give its weight of volatile matter and coke, the percentage of ash, together with the amount of sulphur contained in the coal and coke, and volatile matter in the coke; and, like the other tables, give the relative value of the different coals for the production of gas and coke.

From the exhaustive analyses by Mr. Paterson of coals obtained in various parts of the North of England, we learn the exact value of any particular class specified; the yield of gas per ton of coal; the illuminating power of that gas; the value of a cubic foot in grains of sperm; the value of the gas from a ton of coal in pounds of sperm; together with the weight of coke derived and the percentage of ash contained in that coke. To demonstrate the importance of this table we will take the two extremes, namely, the coal from the South Yorkshire Coal and Iron Company, which yields 12,300 feet of gas per ton, equivalent in illuminating power to 705 lbs. of sperm, and that of the

ANALYSES OF BITUMINOUS GAS COALS BY LEWIS THOMPSON, ESQ.

Name of Coal.	Volatile Matter in the Coal.	Coke obtained.	Ash per Cent.		Sulphur.		Volatile Matter in Coke.
			In Coal.	In Coke.	Coal.	Coke.	
CHESHIRE—Hardcastle	31·5	68·5	5·	7·3	2·10	1·10	1·00
CUMBERLAND—No. 1	25·2	74·5	2·1	2·81	1·30	·70	·60
No. 2	25·6	74·4	1·4	1·88	1·10	·60	·90
No. 3	30·9	69·1	4·	5·8	1·70	·80	·90
DERBYSHIRE—Staveley	40·9	50·1	2·7	4·57	1·20	·80	·40
GLOUCESTERSHIRE—Coalpit Heath	30·1	69·9	5·8	8·3	4·10	2·20	1·00
Whitecroft, near Lydney	34·3	65·7	11·1	16·89	3·10	1·90	1·20
LANCASHIRE—Arley	33·7	66·3	3·6	5·43	1·20	·60	·60
St. Helens	37·2	62·8	1·2	1·91	1·10	·54	·56
NORTHUMBERLAND AND DURHAM—Blenkinsopp	38·	62·	5·1	8·22	1·20	·80	·80
Dean's Primrose	29·5	70·75	2·4	3·4	1·40	·71	·69
Garesfield (Butes)	28·3	71·7	3·2	4·46	·90	·40	·50
Ditto (Cowan's)	29·4	70·6	·95	1·34	·85	·40	·45
Girforth	35·	65·	1·	1·54	1·10	·50	·60
Hastings Hartley	36·6	63·4	2·	3·15	·95	·50	·45
West Hartley	35·8	64·2	4·7	7·3	1·10	·60	·50
Leverson's Wallsend	39·4	65·1	4·9	7·52	1·30	·65	·65
South Peareth	27·8	72·2	1·8	2·5	1·20	·60	·60
Pelaw Main	30·3	69·7	2·6	3·73	1·20	·70	·50
Pelton Main	28·4	71·6	1·41	1·96	1·10	·62	·48
New Pelton	30·2	69·8	1·75	2·5	1·10	·56	·54
South Tyne	36·3	63·7	3·9	6·1	2·10	1·10	1·00
Urpeth	27·8	71·3	1·35	1·89	1·00	·60	·40
Washington	31·25	68·75	2·2	3·2	1·30	·67	·63
STAFFORDSHIRE—Apedale	40·	60·	·75	1·25	1·80	·38	·42
Apedale	38·5	61·5	1·9	3·1	1·50	·82	·68
Heatbern	42·9	57·1	1·75	3·06	1·50	·70	·80
Silverdale	34·	66·	1·95	2·95	1·30	·70	·60
Woodshutts	40·2	59·8	1·22	2·04	·90	·54	·36

TABLE OF THE ANALYSES OF COAL. BY JAMES PATERSON, ESQ., OF WARRINGTON.

		Purified Gas per Ton of Coal in Cubic Feet.	Specific Gravity of Gas Air as 1·.	Illuminating Power of Gas in Sperm Candles of 120 Grains.	Value of One Cubic Foot in Grains of Sperm.	Illuminating Matter in lbs. of Sperm per Ton of Coal.	Weight of Coke in lbs. per Ton of Coal.	Ash in Coke per Cent.
Abram Colliery	Wigan	10,250	0·509	15·62	375·	549·	1307	5·66
Ditto	Ditto	11,000	0·454	14·00	336·	532·8	1315	7·05
Ditto	Ditto	10,500	0·488	15·76	378·	567·36	1361	6·88
Albert Colliery Co.	Newbold, Chesterfield	10,375	0·488	14·13	338·	501·	1402	3 33
Alliance Coal Co.	Wigan	9,325	0·473	14·30	343·	471·	1453	5·31
Anderton Hall	Ditto	11,500	—	18·80	355·	583·	1485	2 72
Aston Hall Colliery	Hawarden, Chester	8,820	0·459	16·46	395·	483·	1384	2·38
Ditto	Ditto	11,250	0·451	16·17	388·	623·43	1368	3·37
Atherton Colliery Co.	Leigh	11,500	0·456	14·66	350·64	576·	1422	3·77
Basley Brook	Wigan	9,500	0·460	16·70	401·	544·	1459	4·59
Birsham Colliery Co.	Wrexham	10,600	0·481	14·50	348·	527·	1336	4·12
Bestwood Coal and Iron Co.	Nottingham	9,540	0·469	15·14	363·36	495·21	1282	6·72
Blackleyhurst Little Delph	St. Helens	9,725	0 400	13·81	331·	460·	1470	2·75
Blainscough Colliery Co.	Wigan	11.970	—	16·39	393·36	672·65	1433	3·23
Brinsop Hall Colliery	Ditto	9,980	0·466	16·45	394·40	562·30	1444	3 60
Bryn Hall Collieries	Ditto	9,540	0·511	15·28	367·	500·	1377	5·64
Ditto	Ditto	10,800	0·458	16·14	387·	597·	1324	5·50
Ditto	Ditto	11,200	0·444	13·03	313·32	501·31	1241	5·71
Ditto	Ditto	11,250	0·448	14·55	349·20	561·21	1463	2·46
Clifton Hall	Ditto	10,730	0·575	17·30	414·	636·44	1464	3·33
Derbyshire New Main	—	11,020	0·452	15·43	370·32	583·	1411	3 21
Derbyshire Silkstone Coal Co.	—	10,775	0·456	14·71	353·	543·37	1465	6· nearly
Ditton Coal and Iron Co.	St. Helens	10,055	0·513	17·26	414·	595·	1470	1·73
Dewhurst, Hoyle, and Smethurst	Wigan	11,050	—	14·40	345 56	545·50	1420	3·37
Foadbank Colliery	Dunfermline	10,530	0·479	14·41	366·	550·57	1245	5·21
Garswood Hall	Wigan	10,980	0·469	16·78	402·60	620·	1435	5·67
Ditto	Ditto	10,820	0·566	16·	384·	593·56	1346	5·79
Garswood Little Delph	St. Helens	9,000	0·417	14·74	354·	455·17	1419	3·
Guy Brothers and Co.	Manchester	9,320	0·500	17·15	411·6	548·	1372	6·66
Haddoch Little Delph	St. Helens	8,936	—	12·75	306·	391·	1398	3·03
Hargreaves, Richard	Liverpool	10,270	0·512	14·72	353·30	518·34	1470	3·33

Hindley Field	Wigan	10,760	0·450	15·26	366·	562·	1314	5·45
Ditto	Ditto	10,750	0·462	15·35	388·	565·75	1374	7·77
Hindley Green	Ditto	11,200	0·452	15·11	366·	585 60	1435	2·28
Ditto	Ditto	9,470	0·479	13·35	220·4	409·10	1315	3·21
Hindley Hall (Roger Leigh and Co.)	Ditto	11,550	0·498	15·36	368·64	608·26	1425	2·11
Ince Hall Coal Co.	Ditto	10,840	0·459	16·52	396·48	614·	1382	5·17
Kirkless Hall Colliery	Ditto	9,730	0·488	15·32	367·70	511·10	1464	4·23
Manvers Main Colliery	Rotherham	11,000	0·457	16·62	399·	627·	1366	2·02
Moss Hall	Wigan	10,800	0·461	16·75	402·	620·23	1444	2·32
New Winning (Blundell and Sons)	Ditto	10,975	0·469	16·96	407·	638·43	1464	4·33
Ditto	Ditto	11,800	0·481	13·92	334·	563·	1461	5·88
Ditto	Ditto	10,150	0·489	14·63	351·	509·12	1400	6·13
Ditto	Ditto	10,300	0·487	14·53	349·	513·58	1460	5·22
Ditto	Ditto	10,000	0·477	14·48	348·	497·	1431	5·83
Pearson and Knowles	Ditto	10,050	0·479	14·87	356·89	512·40	1432	5·27
Peasley Cross	St. Helens	9,000	0·411	12·50	300·	386·	1425	4·75
Pelsall Coal and Iron Co.	—	11,500	0·472	15·31	367·44	603·65	1320	2·44
Rose Bridge Colliery	Wigan	12,600	0·444	15·40	370·	666·	1493	1·71
Ditto	Ditto	10,300	0·444	15·22	365·30	537·51	1315	2·30
Shirland Colliery Co.	Alfreton	11,000	—	13·46	323·	507·	1312	1·85
Ditto	Ditto	9,800	0·500	16·22	389·	545·	1402	1·77
Silkstone and Dodworth Coal and Iron Co.	—	12,240	0·459	16·66	399·84	699·15	1498	0·88
Ditto	—	11,220	0·497	15·87	381·	610·70	1430	1·62
Silkstone Fall Coal Co.	Barnsley	11,290	—	16·98	407·	656·43	1443	0·81
Ditto	Ditto	11,200	0·496	17·	408·	652·80	1431	1·80
Ditto	Ditto	11,670	0·440	15·17	364·	606·84	1395	2·
Syndall Hall Colliery	Ditto	10,150	0·542	17·80	434·	680·	1291	3·22
South Yorkshire Coal and Iron Co.	—	12,300	0·498	16·73	401 52	705·52	1456	1·24
Spring Colliery	Wigan	10,450	0·477	13·31	319·	476 22	1456	3·62
Ditto	Ditto	9,800	0·494	15·22	365·	511·39	1463	2·11
Staveley Colliery Co.	—	9,040	—	11·52	270·	350·	1395	4·32
Ditto	—	10,100	—	12·23	294·	424·	1340	4·50
Swan Lane Colliery	Wigan	9,400	0·521	16·82	404·	542 50	1314	2·42
Tawel Vale Colliery Co.	Ormskirk	10,420	0·457	15·64	375·36	558·75	1360	4·22
Victoria Colliery	Rainford	10,030	0·483	13·63	327·	454·	1264	2·88
White Moss Colliery	Ormskirk	11,400	0·467	15·37	366·88	586·45	1423	2·31
Wigan Coal and Iron Co.	Ditto	11,840	0·471	15·37	367·	620·75	1449	1·79
Wigan and Whiston Coal Co.	Wigan	9,750	—	13·75	330·	459·64	1412	2·94
Ditto	Ditto	12,300	0·494	15·	360·	632·27	1441	1·87

TABLE OF RESULTS OBTAINED IN THE PRACTICAL ANALYSES OF VARIOUS SCOTTISH CANNEL COALS.
BY G. R. HISLOP, ESQ., OF PAISLEY.

		Purified Gas per Ton of Coal. Cubic Feet.	Specific Gravity of Gas Air, 1000.	Illuminating Power of Gas in Sperm Candles of 120 Grains.	Value of One Cubic Foot of Gas in Grains of Sperm.	Value of Gas from Ton of Coal in lbs. of Sperm.	Weight of Coke in lbs. per Ton of Coal.	Carbon in Coke per Cent.
Lesmahagow Main Coal	Lanarkshire .	12,420	688	34·26	824·24	1458·88	1060	86·80
Dykehead, Airdrie	Ditto . .	13,126	716	38·71	929·04	1742·08	1109	84·50
Chapleside, ditto	Ditto . .	13,265	672	35·86	860·60	1630·22	973	81·11
Haywood, Carnwath	Ditto . .	11,706	586	30·55	733·20	1226·10	1135	82·80
Wilsontown, ditto	Ditto . .	11,120	587	29·04	696·96	1007·17	1279	92·20
Cleugh, ditto	Ditto . .	11,894	586	28·15	675·60	1150·80	1193	88·80
Benhar, Whitburn	Ditto . .	10,640	581	28·06	673·90	1024·30	1385	58·20
Crofthead, West Calder	Ditto . .	10,535	516	25·32	607·68	914·56	1234	91·40
Kirkwood, No. 1, Coatbridge . .	Ditto . .	11,615	593	30·04	722·10	1196·20	1002	87·40
Ditto, No. 2, ditto	Ditto . .	10,588	578	28·41	681·80	1026·40	1062	87·20
Tonnochside, Bellshill.	Ditto . .	10,913	576	28·32	679·68	1059·62	1250	82·80
Bredisholm, Bailleston	Ditto . .	10,859	564	27·86	688·60	1037·26	1245	79·80
Braehead, Old Monkland. . . .	Ditto . .	10,033	570	27·06	648·40	930·90	1267	85·80
Allanton, Hamilton	Ditto . .	10,561	518	22·32	535·70	808·20	1272	92·45
Shieldmuir, Motherwell	Ditto . .	9,520	536	23·13	555·10	754·96	1242	91·80
Muirkirk, No. 1.	Ayrshire . .	12,160	609	32·54	781·20	1356·60	1125	95·20
Ditto, No. 2.	Ditto . .	10,658	588	28·34	680·16	1035·60	1165	89·40
Cairntable, No. 1	Ditto . .	11,480	602	32·83	787·90	1292·20	1164	94·04
Lanemark, New Cumnock . . .	Ditto . .	10,602	574	29·23	701·50	1062·30	1241	89·50
Knockshinnock, ditto	Ditto . .	10,230	540	25·55	613·20	895·27	1281	93·80
Niddry, No. 1, Portobello . . .	Edinburghshire	11,615	634	30·62	734·88	1219·37	1037	92·80
Ditto, No. 2, ditto	Ditto . .	11,650	572	27·34	656·16	1092·05	1139	85·80
Kirkness	Fifeshire . .	13,825	610	32·13	771·12	1522·96	1034	75·10
Old Wemyss	Ditto . .	13,220	612	32·52	780·48	1482·28	1036	73·50
Inchgall	Ditto . .	13,520	656	32·72	785·20	1518·42	1026	74·20

Staveley Colliery Company, which yields but 9,040 feet of gas, equal to only 350 lbs. of sperm. Hence it is obvious that the former contains twice the illuminating power of the latter, and yields upwards of 25 per cent. more gas; whilst the advantage in the yield of coke with a lower percentage of ash is also in favour of the South Yorkshire Coal and Iron Company. These are facts that should be well considered by every Gas Company when deciding on the description of coal for carbonization.

The preceding table exhibits the results obtained by Mr. Hislop from a few of the principal cannels out of upwards of 120 kinds from different districts in Scotland. The market value of cannels is very largely affected by the illuminating agents they evolve. Thus we find that whilst Shieldmuir gives a low yield of gas, only equal in value to 754 lbs., another class, Inchgall, gives more than double, or 1,518 lbs. of sperm per ton of coal. Their value is also influenced by the quality of the coke which they afford; a portion of the above number contains from 73 to 85 per cent., and one kind only 58 per cent. of carbon, which limits their use as fuel, and sometimes renders an admixture of a coal which yields a superior class of coke for firing purposes indispensable.

From the preceding we understand the great importance in the choice of coal for carbonizing; and if we further consider that its cost is often a small item when compared with the carriage or freight, it is evident that the proper selection becomes a main point in the prosperity of a gas company, and that the economy effected of two or three shillings per ton in the first cost often literally means a loss of several times the supposed saving. This is particularly the case in works situated abroad, where the freight or carriage is heavy.

In terminating our observations on this subject, we would impress all gas managers with the advice to avoid any new class of coal until its quality has been thoroughly verified by practical experiments; and when making these experiments a good fair sample should be chosen, of not less than a charge of 7 lbs. Quantities of a few grains, as recommended by chemists, are likely to deceive; besides with these small specimens the nature of the coke cannot be ascertained. In gas-works abroad frequently specimens of bituminous shale are offered to the notice of the gas manager. However, in no case that has come under our knowledge have they assisted; but, on the contrary, the specimens have often been the cause of annoyance and trouble.

Coal, and particularly slack, deteriorates by long storage, and this deterioration is augmented when the coal is exposed to the weather. Works which have the facility of obtaining the coal directly, and quickly, from the mine, are placed in a much more favourable position, both in the quantity and the quality of the gas obtained, than other works where a great delay occurs between the periods of getting, and carbonizing, the coal. The cause of this deterioration is difficult to explain, but that such is the fact there can be no doubt, as it is proved daily, and shows the desirability of having frequent shipments at intervals to works abroad, in order to avoid long storage.

CHAPTER V.

CARBONIZATION.

Temperature necessary—Clay Retorts generally employed—Charges—Importance of Dry Coals—Air-tight Doors of Retorts—Incrustation of Retorts—Mode of removing—Hydro-carbons absorbed by Tar—Anti-dip Pipes—White's Automatic Valve—Duration of Charges—West's Charging Apparatus—Fuel for heating Furnaces—Percentage of Coke used for—Necessity for rapid Sale of Coke.

THE first process in gas manufacture consists in submitting the coal to the action of a high heat, whereby its destructive distillation, or as generally termed carbonization, is effected. In practice this is accomplished by placing the coal into retorts of fire-clay or iron, which are previously heated considerably above its point of ignition.

The retort, being charged with coal, is then hermetically closed with a door and luting, or in some cases the door is so adjusted as to be gas-tight without the luting, the gas having no escape except through the ascension-pipe. By these means the coal is decomposed, and the gas evolved, and when effectually done, the residue left in the retort is simply coke—a substance chiefly consisting of carbon, containing neither bitumen, tar, nor other volatile matter capable of yielding a useful gas for the purpose of lighting.

When coal is submitted to a temperature approaching to 600° Fahr.—that is, a very dull red heat as seen in the dark, a degree of heat which slowly chars paper, but does not inflame it—its volatile matter is resolved into tar and oil, and little or no gas is evolved.

Mr. Young, of Bathgate, turned the knowledge of this simple fact to very great advantage, by decomposing Boghead cannel at that low temperature by which oil and tar only were obtained. These were afterwards purified, producing the material universally known as paraffin oil. When the operation is properly conducted, the quantity of gas evolved at a low temperature is very small, in some cases perhaps not exceeding 100 feet per ton, the rest of the volatile constituents being condensed into liquid.

In the carbonization of coal, in proportion as the heat of the retorts increases, so is the quantity of gas augmented and the tar diminished. Thus at a very low red heat as seen by daylight about 6,500 feet per ton are produced, and as the heat increases so is the quantity of gas augmented. The best temperature for iron retorts, compatible with their durability and good yield of gas, ranges from the heat called cherry-red to bright cherry-red; but with clay retorts, that temperature having the colour between a dull and bright orange is generally considered the most suitable, and gives vastly superior results in the production of gas, than can ever be attained by the use of iron retorts, which at the present day are very seldom used; and then only in the smallest of works, where the operations are very irregular.

Clay or brick retorts are now used almost exclusively, alike in works of the largest magnitude as in those making only one million of feet per annum; the principal advantages derived from them consisting in their great durability and consequently economy, as the average estimate of the cost of clay retorts for carbonizing is about one penny per thousand feet of gas produced, whereas the cost of iron retorts was generally considered to be six times that amount. With clay retorts and exhauster the temperature can be raised to that degree that about seventeen per cent. increased volume of gas is obtained from the coal, of an illuminating power little inferior to that derived from iron retorts. The operation of carbonization is more quickly accomplished, as a charge of 2½ cwt. of coal can be carbonized with clay retorts, as readily as another of 1½ cwt. with those of iron. Besides, should circumstances necessitate such a course, the heats of ordinary good settings can be speedily raised in such a manner as to carbonize the coal in a much shorter time than is usually allowed, without the fear of injuring the retorts.

Generally, the charges for the retorts are of six hours' duration, although in our opinion five-hours charges are more beneficial, but an impediment to their adoption is the irregularity of the hours during a succession of days; whereas with the six hours the same benches fall on the same hours continually. Many engineers, however, prefer the higher temperature of bright orange with four-hours charges, by which we often hear of upwards of 10,000 feet being obtained from a ton of Newcastle coal.

All coals for carbonizing should be dry, wet coals are productive of several evils; as, for example, when first charged the humidity is rapidly converted into steam, which carries off a large portion of the caloric from the retorts; when their temperature being reduced, according to the action already explained, by low heats the volatile constituents of the coal are evolved as tar, with a diminished yield of gas. It has been stated by a high authority that with wet coal a large quantity of hydrogen is produced—which, however, does not correspond with our experience—and we are assured that the heat of the retorts is not sufficient to decompose the large volume of steam given off under these circumstances. Besides on several occasions in small works, where an open seal has been attached to the condenser, we have observed the great quantity of liquor flowing therefrom, when wet coals have been charged. Moreover, it has been demonstrated by Messrs. Perrot & Schwartz that by carbonizing wet coals the quantity of olefiant gas is reduced one-third. For this reason, all coals should be kept under cover, with proper ventilation, in order to avoid spontaneous combustion, which is liable to occur when coal is stored in a wet state, in a confined locality.

When retorts are charged, at the time of closing the door of the mouth-piece, the gas should inflame; in the opposite case, should a dense volume of black smoke issue, it is a proof either that the "heats" are too low or the charge of coal too great. And here it should be observed that the word "charge" has two different significations, as it means, the quantity of coal placed in the retorts, or the time the coal is undergoing the process. Thus we talk of a charge of 2 cwt. for each retort, and a five or six hours charge.

One of the modern improvements connected with the retort-house is the air-tight mouth-piece door, invented by Mr. Morton, which requires no luting. The door is supported by a hinge, and so adjusted to the mouth-piece that when closed the cross-bar is secured by a handle, when an eccentric presses the door with sufficient force to prevent any leakage. These doors are made to suit all the various forms of retorts, whether D-shape, round, or oval. The advantages to be derived from them are—dispensing altogether with luting, with all its trouble of trimming and cleaning the lids; avoiding the accidental loss of gas from breakage of the lute; dispensing with the most arduous part of the stoker's duty, the taking off and putting on the lids; and the promptitude with which these mouth-pieces is closed, is admirable. The prices of these lids are moderate, which are repaid by the advantages enumerated in a few months, and only the most ordinary care is necessary to retain them in good working order during a series of years, as proved at the Beckton and other large works.

A very essential point in the carbonization of coal is to keep the interior of the retorts free from incrustation, and, indeed, as far as possible, to prevent it accumulating. This incrustation is a solidification of the heavy hydrocarbon or the richest parts of the gas, and whenever gas is subjected to a high pressure and great heat these are deposited within the retort in great abundance.

This incrustation entails several disadvantages—it obstructs the passage of the caloric to the coal, and consequently increases the fuel and labour; by the space it occupies more retorts become necessary, so increasing the capital invested; and wherever it abounds the coke is always of inferior quality. In iron retorts, where the heats are not so high as in those of clay, supposing both to be subject to the same pressure, this deposit does not take place so speedily; but it is always in excess in the hottest part of the retort, which is generally the closed end, and diminishes towards the mouth in proportion to the reduced temperature.

When clay retorts are at the most advantageous temperature, and the gas in them is under a pressure of about 18 inches—by no means uncommon when the exhauster is not in use—two or three weeks are sufficient for a very inconvenient accumulation of carbon in the retorts; but when the pressure is diminished by the exhauster to about one inch, the same quantity of accumulation would require from two to three months.

The mode sometimes adopted to clear out this carbon is to project from a tube a small jet of steam on to the crust attached to the roof of the retort while it is heated as usual. The oxygen of the steam combines with the carbon which gradually diminishes, and when sufficiently thin it can be easily detached by means of a chisel bar, and on being removed from the roof, like an arch without the key, the deposit of the sides breaks away in large lumps. But in the present advanced state of gas manufacture, the chisel bar should never be employed, as by it often retorts are broken and rendered unfit for service. The proper method of removing the carbon incrustation is by a periodical cleansing; for this purpose the retorts are exposed to the action of the atmosphere, the heats being kept up as usual, and the door is placed in its position, leaving about half an inch space between it and the mouthpiece, when the air enters and gradually cleanses the retort. It is always advisable to clear out this deposit before it becomes too thick; if neglected, its accumulation is very rapid.

In order to avoid the deposit of carbon in the retorts, the pressure should be as low as possible, and to attain this object the dips of the hydraulic main ought never to be immersed to a greater depth than one inch; and if an exhauster be employed, this should be connected directly with the hydraulic main, when it can be worked at "level gauges," so leaving a pressure of one inch on the retorts. When no exhauster is employed, every means should be adopted to lighten the back pressure, by limiting the thickness of the purifying material, and if possible counterbalancing the holders.

Within the last few years attempts have been made to dispense with the dip pipes in the hydraulic main, on the grounds that they give considerable pressure, and that a portion of the hydro-carbons are absorbed by the tar in their passage. Without giving credence to all that may be said in disparagement of the dip, we cannot forget the absorptive action of the tar in the hydraulic main, and that by this some of the richest constituents of the gas are absorbed; and if any proof of this were requisite it exists in the fact that tar on distillation, yields those very constituents.

Thus it is evident that the hydro-carbon vapours issuing from the coal during carbonization, are absorbed by the tar, which, passing into the hands of the tar distiller, are reproduced as naphtha or other hydro-carbons, and are sometimes afterwards employed in the production of "air gas" or carburetted air. Hence that which was lost in the first instance, and should have been conveyed with the gas, is eventually consumed by the intervention of air. That this is a palpable error in gas manufacture there can be no doubt, since it is admitted by several writers on the subject that tar has a great affinity for the hydrocarbons, and, once absorbed, they can only be separated by distillation, as already observed. With the view of remedying this evil, within the last few years various inventions of anti-dip pipes have been produced, possessing more or less merit, but in nearly all the attention of the workman is required to open and close them at every charge. This, however, is dispensed with in White's automatic valve, which we believe to be the best method of obtaining the desired end.

This apparatus consists of a small clack-valve placed at a slight angle to the perpendicular position, enclosed in a box, in connection with each ascension pipe. The valve is constructed in such a manner as to open outwards with a pressure of two-tenths of an inch of water; thus, on the retort being charged, the valve is opened by the gas, and remains open so long as gas is produced, and that pressure exists. But when the supply ceases, the valve closes and prevents the gas returning. On applying this valve in some cases the hydraulic main is dispensed with, and the ascension-pipe is continued by a bend and horizontal pipe, at right angles to the former, to the back of the single benches, where a horizontal pipe communicates with each of the valves.

These valves in practice as in theory are perfect, as by the action of the weight the gas must be shut off when desired, and yet by the lightness of the valve beyond the slight pressure mentioned, it offers no resistance to the passage of the gas. By disinterested persons we have been informed of the complete success of the automatic valve, after having been in operation about a year without requiring the least attention, and which has resulted in a larger yield of gas per ton of coal carbonized, and of superior quality to that obtained with the hydraulic main.

In a remarkably well-conducted works, we have seen these valves in combination with the dip, to which they act as a by-pass, and give the greatest satisfaction.

When the ascension-pipes are placed too close to the furnaces, or when the wall of the furnace is not sufficiently thick, the pipes are heated to such a degree that the tar in its passage is deposited therein as pitch, thereby causing a speedy obstruction.

Some kinds of coal yield their gas with much greater facility than others; for instance, the better classes of cannel will deliver their gas in four hours, whereas a like quantity of slack when submitted to the same heat would demand six hours. Hence, according to the class of coal employed, so will be the duration of the charge.

When caking coal is charged in a retort, after a time it begins to intumesce, or boil, emitting its gas from each bubble; subsequently it becomes a black doughy mass, and when nearly all the gas is evolved it begins to increase in temperature, and on becoming red-hot attains the brittleness of coke; and once the mass is incandescent, the coke should be withdrawn from the retorts, so as to prevent the emission of the sulphur compounds, which are then generated.

In small works, which do not permit of the necessary men being employed to work double retorts, single retorts, generally about eight feet long, are used. The beds or ovens for these are placed side by side, and extend the length of the retort-house. In works of larger magnitude they are placed back to back, are open throughout, and are charged simultaneously at both ends. These are called double or through retorts.

Retorts are sometimes charged by means of the shovel, when the process is necessarily more tedious than with the scoop, and the expenses of labour for carbonization increased. With the scoop three men at least are necessary for each "shift" for day or night service.

The number of men required to carbonize a given quantity of coal depends on the size of the works. At extensive establishments each man carbonizes from five to six tons of coal per day. In Scotland formerly (and perhaps the system at present exists), it was sometimes the custom for the stokers to be engaged by piece-work.

As a point of economy in carbonization, the retort-house should be paved, that portion near the benches with hard fire-bricks, the other with Yorkshire flagging. Each ash-pit should also be provided with a plate by which the opening is covered during the time of charging the retorts, in order to prevent any coal from falling into them. At the end of each charge the place opposite the benches should be swept up, and the coal placed for the next charge, so that the retort-house is always in an orderly condition, all of which is essential to proper working.

The coke as drawn from the retorts should be quenched, and sold as quickly as possible, in order to avoid the labour of stacking, and the loss arising from storing, by the coke crumbling to breeze. Wherever coke is stacked for a considerable time, the loss is very great, as is made evident by the cart-loads of breeze which are removed at the time of clearing the stack. We believe that it is more profitable to sell the coke as produced say at 12s. per chaldron, than to stack and keep it for twelve months and sell it at 18s.; for it is not only in the loss of the coke which is crushed into breeze, but the whole of it is rendered smaller, and thus depreciated in value.

Stoking by machinery has been repeatedly attempted, but the only successful plan with which we are acquainted is that invented by Mr. West, as employed at Maidstone and several other works. This apparatus is extremely simple and effective; for it skilled labour is unnecessary, and the economy derived from its use is sufficient inducement for its general adoption. Had the inventor been a more prominent member of the gas profession, he would have experienced little difficulty in introducing his excellent invention. However, it is being gradually adopted by several works of considerable magnitude, and in due time its value will no doubt be fully appreciated.

FUEL USED IN HEATING FURNACES.

The fuel commonly used for heating the furnaces is the coke produced in the retorts after the gas is expelled; the quantity used of course varying according to the quality of coal and coke, the construction of the furnaces, and the magnitude of the operation. When Newcastle coal is used, the carbonization is seldom effected, except in very extensive establishments, with less than 22 per cent., or rather less than one quarter of the coke obtained; that is to say, to carbonize a ton of coal, about 8 bushels, or 3 cwt. of coke will be required as fuel for the furnaces.

Cannel coal does not give a coke sufficiently good for heating the retorts, consequently in most Scottish works an inferior kind of coal is employed for that purpose.

Coal is usually spoken of by weight, and coke by measure. Newcastle coal generally yields about 1 chaldron of 36 bushels, or from 13 to 14 cwt. of coke for every ton of coals.

The quantity of coke which remains for sale after heating the retorts depends on various circumstances, such as the magnitude of the works: the description of setting of retorts: whether these are constructed on scientific principles, in order that the fuel may be thoroughly effective, and no more heat is allowed to radiate than can be consistently avoided: or whether the settings are built without these considerations. Essential also to strict economy of fuel is proper care in controlling the dampers of the benches, so that there may be a sufficiency of draft, but avoiding any excess: as by an insufficiency the fuel will not give the desired heat, and an excess will always be attended with considerable waste of fuel. Deep and narrow furnaces are generally preferred for retort settings, as by these means the air in its passage through the fuel becomes highly heated, approaching a white heat. The hot air, or caloric, is afterwards dispersed through the setting, and its passage therefrom is checked by the damper of the flue, placed at the entrance to the main flue.

Within our recollection, at many gas-works the damper was unknown, and as a natural consequence the fuel used for heating the furnaces was excessive in the extreme. This, under such circumstances, must always be the case, as the damper is the point of separation between the interior of the oven and the atmosphere, and is really the means of preventing the escape of the caloric. Therefore the smaller its orifice the more effectually will that escape be prevented; however, at the same time the orifice is required of sufficient capacity to allow the proper draught, or current of air to the furnace. With a moderate draught for a setting of five retorts, each capable of distilling two tons of coal in the twenty-four hours, the opening in the damper will not be more than five square inches; but this will be controlled by the state of the atmosphere, which has much more influence in the manufacture of gas than is generally believed.

An important consideration also is that the fire-bars of the furnace should be properly clinkered, in order that the air may have a free passage to the fuel, and that the ash-pan should be properly supplied with water; which, in addition to preventing the furnace-bars from burning out, by the evaporation of steam, becomes a source of fuel, as it is decomposed into its two elements, hydrogen and oxygen, the former a combustible, the latter a source of combustion.

In works of the largest capacity the fuel used for carbonizing often does not exceed 18 per cent. of the production, and we are assured by several gentlemen, engineers of moderate-sized works, that their carbonizing is effected with 22 per cent. of the coke produced. Of course it is understood that under these circumstances only caking coal is carbonized. Hence, if we suppose 36 bushels of coke to be obtained per ton of coal, less than 8 bushels of coke would be sufficient to carbonize that quantity.

According to our experience 25 per cent. of the coke is sufficient in all works of moderate capacity for carbonizing, and whenever this is exceeded the operations are badly conducted. In smaller works of a make of fifty million feet per annum, the percentage of fuel for carbonizing is increased; and as works diminish in magnitude, so does the fuel for carbonizing augment, until arriving at those with a "make" of one million feet per annum, where all the coke will be required to heat the retorts.

The percentage of fuel is often influenced by the manner the coke is sold; thus if we suppose that to be measured with strict care, it is evident that a greater quantity will be represented as sold, and consequently less will be estimated as being consumed in the furnaces: whereas if the coke is freely measured, the estimated percentage employed in the furnaces will be augmented; and so uncertain is this method of determining the amount used as fuel, that we find by the returns of the Metropolitan gas companies three years ago, one company charged 40 per cent. more per chaldron than another, and yet no great difference existed between the amounts received for coke of the two companies, per ton of coal carbonized.

When there is not a sale for the tar, or when there is a great demand for the coke, tar may be employed advantageously for heating the retorts, thus entirely replacing coke for that purpose. For this object sometimes the settings are built with a large arch immediately over the furnace, which is rendered necessary on account of the tar acting as a flux on any brickwork in immediate contact with it.

When employing tar as fuel the best method that we are aware of is represented in the annexed figures. The elevation (Fig. 1) indicates the position of a furnace-door as ordinarily employed, and if we suppose tar is required to be used, the space of the door would be bricked up as shown, leaving an orifice, *a*, for conveying the tar, water, and air into the furnace as represented in section in Fig. 2. There is also another orifice, *b*, of about the same dimensions as the former (2½ inches square) at the bottom, for the supply of air. Also the gutter, *c*, which may be of angle-iron or a piece of fire-clay slab, projecting about 3 inches within the wall, and the same distance on its exterior.

The small pipe extends to the side of the buckstave, to a height of 5 feet from the ground, where it is open, and surmounted by a funnel of about 3 inches in diameter, into which the tar drops. Another pipe brings the tar from the hydraulic main, which is always preferable on account of its freedom from dirt, and its liquid state. This pipe terminates about a foot above the funnel, and to it is attached a lantern-cock, provided with a few inches of ¼-inch lead pipe, which can be bent in such a manner as to cause the tar to flow with facility into the funnel. In addition there is also a small pipe to convey a small portion of water, supplied by a tap, into the funnel.

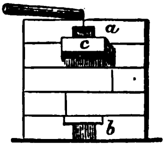


Fig. 1.

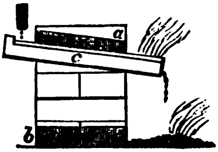


Fig. 2.

Should the tar be required to replace coke, the fire-bars should be removed, when the ash-pan is filled up with lime or clinkers, or the two combined, to the level of *b*. All being arranged as described, it is ready for use. The alteration from coke to tar may be made in an hour.

The tar from the hydraulic is then adjusted by the lantern-cock to a stream of about one-twelfth of an inch in diameter, and the water is regulated to flow in drops of about eighty to the minute. The tar and water flow by the pipe on to the gutter, and thence into the furnace, as shown in section, producing a very vivid flame at the point *a* in section, whilst the excess of tar falls below, where accumulating as a solid in front of the orifice *b*, it is rendered combustible, producing heat by the air entering at that orifice. Practice will soon indicate the proper quantity of tar required, as well as the precise size of the orifices for the admission of the tar and air.

A furnace may be heated by this system during several months, when all that is necessary is the proper delivery of tar and water, and occasionally, once in three or four hours, to pass a rod into the channel *c* in order to clear out any obstruction, and once in twelve hours to remove a few ounces of the accumulation in front of the orifice *b*. When properly arranged no smoke issues from a furnace heated by tar.

There is one point that should be impressed on the mind of every manager, that is the necessity for realising a good portion of the cost of coal from the sales of coke. In some places where coal is cheap and coke much in demand, the cost of the coal is repaid by the returns from the residual in question; and in all localities, whether in the tropics or the most northern countries, in works of large and medium capacity, at least 33 per cent. of the cost, supposing in all cases this to be caking coal, should be derived from the sales of coke; and whenever this is not effected it arises from a want of proper management, which may be due to imperfect settings of retorts, or inattention to the dampers, or bad administration.

Recently we saw at the Phœnix Gas Works a definite measure for a sack employed. This is a cylinder of light material of 1 foot 6½ inches diameter by 2 feet 11½ inches high internally. The general use of this would avoid the vagueness at present existing in the sales of coke.

CHAPTER VI.

GENERAL CONSTRUCTION.

Remarks on the choice of Site—Plan of Works—The Retort-house and Buildings—The Coal-store—Purifying-house—Engine, Boiler, and Exhauster-house—Station-meter and Governor-house—Chimney Shaft.

CHOICE OF SITE FOR GAS-WORKS.

WITHIN the last few years the application of gas has extended in a remarkable manner, alike for lighting, for heating apartments, and cooking, as well as for other domestic and industrial purposes; which extension is no doubt due to the improvements which have been introduced into every department of its manufacture and distribution, and its reduced price.

Among the most important of the former are the means of transporting coal, and at the present day, instead of imitating the choice of sites of the Chartered Company at their first establishment, when they placed all their stations at a considerable distance from water-side communication, the first consideration of gas companies, is to choose sites by which economy in the transport of coals and other materials is secured. Thus we find works having only a make of 50,000,000 feet per annum provided with their siding in connection with a railway, from which the coal is carried into the retort-house ready for carbonizing; and in some instances gas-works are placed in direct communication with the mines, so that the coal passes direct from the mine to the retort, through the hands of the stoker only. Thus, when compared with former times, when the coal was shipped, afterwards transported by barge, conveyed by canal, and subsequently carted, and trimmed before carbonizing, all of which materially increased its cost, the present system shows on this point alone a vast improvement and economy.

In other cases the river and canal are the means of transport for a gas company. An example of the former exists at the Beckton Gas-Works, the largest in the world; where there are high-level and low-level lines of railway extending throughout the works. Also a pier or landing-stage at the river, with six steam cranes, by which three or four vessels can be discharged at one time, and no less than 10,000 tons of coal can be delivered into the works in one day. At these works there are 2,100 retorts or 4,200 mouth-pieces in action in the depth of winter, producing 24,000,000 cubic feet per diem, and on the average 2,000 men are engaged daily. Locomotives are also employed for propelling the coal and coke waggons; steam-power is used for pumping the ammoniacal liquor and tar; and finally, this establishment has a special line of railway of about two miles long for its service. Such is the gas-works of Beckton, which, whether regarded for its magnitude or efficiency, must be pronounced the most complete in the world.

But with all these resources, all these appliances, that works is not placed in a more favourable position than many of the medium-sized establishments, for the simple reason that its very magnitude necessitates these extraordinary means of discharging vessels and transport; and, it may be observed, that works of the smallest description are capable of producing the same quantity of gas from a ton of any given coal as the largest, provided they employ the same vigilance and heats, with the same description of retorts; and in a few cases medium-sized works, by reason of their limited capital for a given quantity of gas produced, are placed in even more favourable conditions than the large works in question.

Nor does the important change in the operations of gas companies consist only in the economy of transport, but also in almost everything connected with gas. Improvements have been introduced in the means of carbonizing and purification; mains have been increased threefold within the last 28 years; during that period clay retorts have become almost universally applied; vast improvements have been made in the means of consuming gas, in order to obtain increased light therefrom; also in the method of controlling the pressure in the mains in hilly districts; all of which have been introduced within the last few years. By these improvements the cost of the production of gas has been materially diminished, which has enabled the companies to reduce its price to the present scale, with advantage to themselves and to the benefit of the public; whilst the employment of gas has become more general, for its various applications to heating and cooking, as already enumerated.

It may be briefly stated that the large quantity of coal consumed in a gas-works renders it desirable to avoid any superfluous expense in its transport; therefore means should be adopted to attain that end, and although it may demand extra capital for its realization, when the interest of this is fairly compared with the saving likely to be effected, it will be found in all cases advantageous to choose the site, either in the immediate vicinity of a river, a canal, or a railroad. It is true that a greater length of mains may be required in some instances, which will enter into the estimate of the cost, but this will be amply compensated for.

However, another point for reflection is the best neighbourhood for the disposal of the coke, as it is well known that the nearer the works are to a population, the more facilities are offered for the purpose in question. There are other circumstances depending on the relative value of property, the means of acquiring it, the nature of the ground, whether suitable for the economical construction of the edifices, or if liable to be submerged by heavy floods. These are points which demand serious attention. Lastly, the sanitary question has to be considered, by the adoption of a locality where there is no probability of interference on the part of the local authorities, who are too often disposed to be antagonistic to the gas company.

Years ago objections were raised against placing gas-works in the lowest part of the district, in a town having a great difference of level, and where one part was considerably higher than another. These objections were based on the fact, that the pressure in the mains augments considerably according to the increased elevation; which augmentation is usually estimated at one-tenth of an inch of pressure for each ten feet, or one inch for 100 feet of increased elevation, assuming there is little or no draught from the main. Thus if we suppose the most populous part of the town to be situated 200 feet above the lowest, and the mains supplying the locality to be charged with gas, then if the pressure were at level gauges at the lowest point, it would be two inches in the higher localities; and this existing throughout the whole of the day, the loss from escapes under these circumstances would be considerable. This at one time was urged as an objection against placing the works in the lowest part of the district; which has, however, been removed by the invention of the main regulator to which we will hereafter refer. Moreover, as the lowest part of a town offers the greater facilities for the transport of the coal, in the majority of cases this will be the most favourable position for a gas-works.

It, however, happens very unfortunately, according to our observations, that the smallest of works, in which the strictest economy is necessary in order to earn a dividend, are often situated a considerable distance from the railway, by which the cost of the coal is greatly increased. In such cases, whenever the question of extension may arise, it should also be directed to a removal of the works, or at least the retort-house, to a more eligible position, for gas is far, very far, from attaining its full development.

Plan of Works.

The art of designing and building a gas-works is generally beyond the requirements of the gas manager; but as in many cases he is left dependent on his own resources, we give a few hints with the hope that they may be serviceable.

Previously to the arrangement of the plan of works, the nature of the ground chosen for the site should be ascertained, which is readily done by sinking a pit to the desired depth of the foundations of the intended gas-holders, when a guide is obtained as to the mode of construction and the cost. Should water be abundant within a short distance of the surface, then in most cases cast-iron tanks for the gas-holders will have to be decided on. If the substratum be of clay, ordinary earth, or gravel; a brick, stone, or concrete tank for the gas-holder can be constructed with facility and economy, according to the nature of the material most available. Should the site be "made ground," that is ground which had formerly been transported from elsewhere, then extraordinary precautions in the foundations become necessary; and should rock be encountered, the question then arises whether it would be more advantageous to excavate and build the tank in masonry, or avoid the excavation by erecting an iron tank.

Lastly, in the event of the ground being marshy, the depth of the solid substratum should be ascertained, which is accomplished by probing with a ¾-inch round iron bar in a vertical position, and in the event of the solid not being found at a convenient depth, in many cases it may be advisable to choose another site, in order to avoid the risk and expense attending the construction in such ground. But when the solid is found at a reasonable depth, it then becomes a consideration whether the excavation of the whole of the buildings shall be continued to that point, or whether the foundations and holder shall be built on piles. The limits of this work prevent us entering more into detail on these points.

The price of building materials and their nature must also influence the arrangement of a plan of works. In some parts bricks and puddle are abundant and cheap; in other places neither are to be had, unless at an enormous cost for transport, which renders their employment entirely out of the question. Whatever may be the nature of the building material in the locality where the works are to be erected, it is always wise to adopt it, and should the bricks differ in size with those used in England, it is unwise and costly to attempt to get others made.

In designing a new works there are a few rules to follow; and amongst them are, to construct in such a manner, that at a future period, when required, the works may be increased without much demolition. The retort-house may be so arranged as to be doubled hereafter; the ground so disposed as to admit of extra gas-holders, and sufficient space left for increase of purifiers. The entrance of the works ought to be placed, when practicable, at that part of the site, nearest the locality to be supplied.

In the disposition of the various buildings, the manager's or foreman's dwelling should be at the entrance, in order that all may be under the immediate notice of the residing responsible person. The offices, store-rooms, and weigh-bridge—for the purpose of weighing the coal as it enters, and the coke, when sold by weight, as it leaves—should immediately adjoin the dwelling. A plurality of entrances to a works ought to be avoided.

For the purpose of preventing the expense of unnecessary transport, the coal-stores, coke spreading floor, and shed for coke should adjoin the retort-house. Sometimes a part of the coal-store is paved with bricks on edge, which serves for spreading-floor, and for quenching the coke.

The purifying-house, tar tank, lime, and other purifying material store, are generally separated from the rest of the works, and placed where they may be considered the least offensive. When there is plenty of room the gas-holders are usually placed at some distance from the other buildings; but provision should always be made for future extensions.

Old works, which have been altered frequently from time to time, to suit the demands on them, do not afford the same facilities for excellence of design as those of more modern construction.

The buildings of gas-works of the present day are far superior to those of even twenty years ago. Now in the majority of cases they are highly ornamental structures, obtained by a superior class of gas engineers, at a slight augmentation of the capital formerly required for the massive unsightly edifices then in existence.

We are indebted to Mr. Wyatt, the constructing engineer of the Gas Light and Coal Company, for the drawings of the elevation and plan of a gas-works suitable for a town of 10,000 inhabitants, which forms the frontispiece of this volume. In the drawing the elegance of design, characteristic of that gentleman, is obvious, which is acquired at a cost not exceeding that of the plainest building as often constructed, arising from the fact that all superfluous material is dispensed with and only that actually demanded for the edifices, with suitable ornamentation, are adopted. As may be observed in the drawings, the whole is laid out with skill, the various buildings are so situated as to insure economy in the operations, and ample provision is made for extension. All the parts being described, no reference to the drawings on our part is necessary beyond the simple statement, that the whole may be taken as a model of design.

The capital required for gas-works is variable: for modern works from £500 to £800 per million feet per annum is about sufficient; or if the capital be estimated according to the population, from 25s. to 35s. per head may be calculated. The capital of old-established works usually surpasses these estimates, and in some instances the excess is very material, arising from the high price formerly paid for the mains, apparatus, and the necessary contingencies attending their first establishment. The general improvement in the modern construction of the various apparatus, contributes also to the diminished price.

When gas-lighting is properly developed, which mainly depends on the company supplying, according to the quality and price of the gas, and the facilities afforded for its adoption, the average consumption per head is from 2,000 to 3,000 feet per annum. Whenever the consumption of a town is proportionally small, as a rule, it arises from mismanagement, or want of energy on the part of the company.

In some few instances, however, the capital of companies is extravagantly great, when the price charged for gas is high in proportion; whilst in other cases the capital has been reduced to the lowest extent per 1,000 feet of gas produced, by judicious management, and setting aside a portion of the profits realised, for the purpose of improvements and extension.

An ordinary gas-works comprises the retort-house, coal-store, purifying-house, engine and exhauster, station-meter and governor houses, valve and regulator room, workshops, dwellings, and offices, with the ordinary appliances for testing the quality of the gas, the yard and chimney, together with the necessary plant for the manufacture of the sulphate of ammonia, all of which will be treated upon in due course.

THE RETORT-HOUSE AND BUILDINGS.

The retort-house, as its name implies, contains the ovens, or, as more generally termed, "settings" or "benches" of retorts, in which the operation of distillation or carbonization of coal is conducted. With very few exceptions this is a rectangular building, covered usually with iron principals, and slates or tiles, and sometimes, although rarely, with sheet-iron.

The retort-houses of large works some years ago were limited to 50 or 52 feet in width, but they are now generally built 75 feet wide, whilst the largest retort-houses of the Beckton works are 100 feet in width and 480 feet long. As this work, however, is intended for those interested in small establishments, our attention will be more particularly directed to them.

For the very smallest of gas-works, having only one retort, no rule concerning the dimensions of the retort-house can be given, beyond the simple observation that for the proper working of the rake, a clear space equal to at least one-half more than the length of the retort should be allowed.

In small works, the retort-house is usually about 26 feet wide, which, allowing 12 feet for the width of the retort stack with the space that is usually left between it and the wall, together with the mouthpieces, leaves 14 feet clear for working. There should always be an intervening space between the ends of the stack and the walls of the retort-house; as in the absence of this, when the stack abuts against the wall, the latter is bulged out by the expansion of the brickwork on its becoming heated. In retort-houses of this width, of course only single settings of retorts can be employed. But when the number of the benches or ovens permit of it, then double benches, where the retorts are set back to back, with a firing floor on each side of the retort-house, are usually constructed.

The flooring of a retort-house should always be kept in good repair, the slovenly method of leaving it in recesses and ruts, as sometimes observed, is reprehensible, as by these ruts the coke is jerked out of the barrow, and as the flooring cannot be properly swept after each charge, it is attended with loss; besides, in a gas-works, like every other establishment, considerable order is essential to success.

The roofs of some retort-houses are formed, as observed, with iron principals and sheets, which may be desirable where rigid economy is necessary, but generally the economy is very misleading, as when iron sheets are exposed to the action of the steam, arising from the process of quenching the coke, and the vapours of the retort-house, their durability when of ordinary thickness seldom exceeds seven years. With galvanized iron the duration is somewhat increased; and unless Professor Barff's or Mr. George Bower's system of preserving iron may be found suitable for this part of a gas-works, we would certainly recommend the use of slates for the purpose; by which, however, in consequence of the principals and laths being required of greater strength than when iron sheets are used, the cost is materially increased.

For ordinary small buildings the front and back walls of the retort-house need not exceed 9 inches thick; usually the sides are made 14 inches; and in constructing an essential point is to avoid a draught passing through the building. In larger works these dimensions are augmented according to the magnitude of the building.

A few of the largest establishments have the retort-house very differently arranged to those of the great majority. In the centre, and extending from end to end, are a series of arches built on suitable piers. On these are constructed the ovens or benches, the piers of which correspond with those below. On a level with the furnaces of the retorts there is a stage or firing floor, where the stokers work when charging or drawing the retorts. This is about 6 feet 6 inches from the ground, and is commonly formed by cast-iron columns and plates, extending on each side throughout the length of the retort-house, leaving an opening of about two feet wide immediately in front of the furnaces, through which the coke drops when drawn from the retort into the space below, which is called the coke-hole, or coke-vault.

The coke-vault possesses some advantages, for where it exists the stokers are not exposed to the continuous heat of the coke when drawn from the retorts which falls immediately into the vault, where it is quenched by other men. Moreover, the furnaces are also clinkered from below, which saves some trouble; and the convenience of loading the coke direct into the carts from the coke-vault is also a recommendation. The objections to the coke-vault are the expense in construction; the coke in falling breaks, and is further injured on account of the very limited space for spreading, extinguishing, and storage. There are few works, and these only of the largest magnitude, which have coke-vaults attached to the retort-house.

In large works of the present day the retort-house is employed as a coal-store, for which purpose their width is very considerable.

Generally the ovens employed in large as well as medium sized works are built on suitable foundations, ensuring solidity to the structure, and preventing as much as possible radiation of heat from beneath. In the event of the foundations being in gravelly soil, an increased thickness will be desirable to prevent loss of caloric at that point. The coke when drawn from the retorts falls into iron barrows, and is wheeled away to a separate place for the purpose of quenching.

In retort-houses of this description, the tops of the ash or evaporating pans, are a few inches below the level of the ground, which is usually paved with fire-bricks on edge. Sometimes cast-iron plates have been tried as a substitute for brick paving, but the metal conducts the heat to the feet of the men with such facility, as to render it objectionable.

The benches of the retorts are either placed side by side, the whole length of the retort-house, and having one charging floor; or as in medium-sized works, where retort settings are placed back to back. In this case a building containing say sixty single benches, thirty of them have their open ends or mouthpieces on one side of the retort-house, the other thirty mouthpieces being on the other side, and a 9-inch or 14-inch wall separates the benches. These are called single settings. This method was superseded some years ago by dispensing with the partition wall, and thus the two single beds form one continuous oven, each retort being about 18 or 20 feet long, open throughout, and having a mouthpiece at each end, which are called double beds, or through retorts. The economy derived from this plan is very considerable, but they can only be employed in large establishments, where there are at least six stokers, to charge both ends simultaneously. At a works we recently saw through retorts changed to single.

In deciding on the dimensions of the retort-house, every consideration must be made, not only of the present requirements of the locality to be supplied, but also that of the future; for gas, even at the present day, is very far from being fully appreciated, and it is impossible to anticipate the various future uses to which it may be applied; but the experience of the past demonstrates the necessity of making every reasonable provision for extension. It is also important to have a good margin, and not to estimate the power of carbonization too highly; for by unforeseen circumstances the supply of the ordinary coal may be temporarily discontinued, when recourse must be had to that of inferior quality, which yields less gas, and in consequence requires more retorts.

No definite rule can be laid down for the dimensions of the retort-house; this must entirely depend on the mode of setting. With one kind of setting having a given number of retorts of given dimensions, considerably more coal is carbonized than with another; it also depends whether they are single or double, the kind of coal employed, and other circumstances.

There is nothing peculiar in the construction of the walls of the retort-house more than other buildings of the same height. Of course precautions should be taken to secure a good foundation, to extend the base by footings, and where necessary to use piling or concrete according to the nature of the foundation. On these points no general directions can be given, as the treatment must vary with the special circumstances of the case; the general rule, however, applicable to ordinary foundations will apply here.

The cost of erecting retort-houses will of course vary with the price of labour and building materials in the district. The magnitude of gas-works and plant is generally estimated by their annual production; thus a works of "twenty millions" signifies a production of that number of feet of gas per annum, and in the height of summer will produce about 30,000 feet, and in the very depth of winter about 90,000 feet, daily. In a works of sixty millions per annum the minimum production will be 90,000 feet and the maximum 270,000 feet per diem. In modern large works retort-houses are built in blocks, having free communication with each other, and provided with a ventilating shaft constructed of wrought iron, having a valve or door by which the heated atmosphere of the building is considerably moderated, contributing much to the comfort of the men. And to the credit of many engineers it must be said that the comforts of the men employed in their respective companies have had their greatest consideration. In some gas-works libraries are established, in others baths and mutual benefit societies; and there are gas-works that can boast of having a musical band, composed of the stokers and men of the establishment—circumstances alike praiseworthy to the employers and employed.

THE COAL-STORE.

This is generally attached to the retort-house, with every facility of communication for the purpose of transporting the coals. The dimensions of this building must depend on circumstances. If the railway is the means of transport, then small stores may be sufficient; but should the ordinary means of obtaining the supply of coal be by sea, river, or canal, then in order to provide against the probability of frost, or loss or delay of vessel, the store should be ample for a proper supply, and whenever there are increased difficulties in obtaining the coal the store should be augmented in proportion. It is sometimes advisable to have the coal-store sufficiently large so that in summer, when not required for coal, and coke is abundant, it can be converted into a store for that residual. When employed as a spreading-floor it should by all means be paved with fire-bricks, as stone is liable to crack with the heat. When not used for that object ordinary common paving will answer the purpose.

As already mentioned, it is highly desirable that the coke should be sold as speedily as possible after it is produced.

PURIFYING-HOUSE.

The purifying-house has the sides open, to permit a good current of air to pass through the locality and carry off any noxious gases. There should also be a ventilator in the roof, so that in the event of the lutes "blowing," the gas may escape readily at the top. The roof of the purifying-house is usually of wooden principals and tiles. Iron would be very speedily destroyed by the action of the sulphur emanating from the waste purifying material. In some works the purifiers are uncovered, which has the inconvenience of unnecessarily exposing the men at times to the inclemency of the weather, and ought always to be avoided by a suitable roofing.

According to a modern construction, the purifying-house is built of a ground and two upper floors, of which the uppermost and lowest serve as reviving floors for the oxide.

The purifiers are on the first floor, and in the centre of each purifier is a shoot, through which the foul oxide passes to the floor below, and when requisite the door on the top of the shoot is luted. By mechanical appliances the oxide is lifted from the bottom to the top floor, from where it passes down a shoot into the purifier to be charged. The saving of labour and the rapidity of action are both recommendations to this system of working.

ENGINE, BOILER, AND EXHAUSTER-HOUSE.

In the most moderate sized gas-works at the present day the steam or gas engine is an important auxiliary. Formerly the only use for an engine in a works was for pumping water, or for keeping in motion the wet lime purifiers, and in many works of considerable capacity, where neither of these were requisite, no engine existed. The use of clay retorts has caused motive power for working the exhauster to be introduced into works of all dimensions, except the very smallest kind.

In large works the engine, boilers, and exhauster, being attended by the same man, are generally in the same building, and more care is usually displayed in this than any other part of a gas-works. The edifice is often constructed with taste, and is no doubt an inducement to the men who have charge of the machinery to keep it cleanly and in order with the building itself.

In small establishments the exhauster is generally adjoining the retort-house, the stoker having charge of it. The improvements recently introduced into gas engines, by which they are rendered practical and economical motors, should induce every gas manager to adopt them, on account of their safety, efficiency, and as an example to consumers to employ them.

STATION-METER AND GOVERNOR-HOUSE.

These, like the engine-house, should only be accessible to the manager or foreman, or the man in charge.

When there are several gas-holders together, it is not uncommon for the station-meter to be placed close to them, and the valves of the various gas-holders fixed adjoining the meter-house. On other occasions there is a distinct house for the valves; but more commonly they are attached to their respective holders.

The governor is sometimes placed in the same building as the station-meter, but more frequently a detached building is constructed expressly for it. In large works there are several lines of mains issuing from the works, each of which has its corresponding governor, with the various pressure gauges and pressure registers. And in establishments situated at a distance from their distributing stations a telegraphic communication exists between the various localities, as well as the company's offices.

Chimney or Stack.

The action of the chimney shaft has been already explained, and, as shown, high stacks possess an advantage in consequence of their great draught permitting a reduction in the opening of the damper; but against this they present the evil, that, if the dampers are not well looked after, the draught occasioned by them will cause the fuel in the furnaces to be consumed very extravagantly without any good result.

High stacks are constructed principally for the purpose of carrying off the smoke or offensive products to a great height, where they are diffused over a large space, and a nuisance which otherwise would exist is prevented. In some chemical manufactories the stacks are made of great dimensions—one near Glasgow is 400 feet high. By means of this all noxious gases that may be generated are carried to, and issue from the top of the chimney, without the least prejudice to the neighbourhood.

The largest chimney for a gas-works is that of the Edinburgh Company, and is a fine piece of building, being 329 feet above the level of the ground, perfectly plomb, and without the slightest crack or fissure throughout the height. The current therein, when in ordinary working order, is equal to an exhaust of two and a half inches of water—a strong current in an ordinary chimney seldom exceeds half an inch exhaust. The cost of this stack, with the lateral flues, was upwards of £4,000.

Chimney stacks for gas-works are constructed in various manners, the simplest and cheapest being the square form; but these are somewhat unsightly, and, offering greater resistance to the wind, require to be built strong accordingly. Some stacks are made circular and others octagonal; the latter, when surmounted on a square pedestal, with a neat capital on the summit, has a remarkably good appearance, whilst the cost does not exceed that of the circular form.

Chimney stacks, unless when placed in the centre of the beds, should never be built in the retort-house, as they occupy the space unnecessarily. Wherever constructed, they should always be detached, and, on account of their great weight and height, extraordinary precautions are necessary in their foundations. The area of these must be determined according to the degree of solidity of the ground where erected; the softer the soil, of course the greater will be the area required for the footings. The pedestal for the base is usually square, one side of which is one-eighth of the total height of the shaft.

Stacks for gas-works are always lined with fire-brick either for a portion or the whole of the height. Sometimes the lining is detached from the chimney, leaving a space for a current of air to pass between the former and the latter, which prevents the stack cracking. Small chimneys are usually constructed entirely of fire-bricks.

A mistaken notion often prevails, that by materially contracting the stack at the top, the draught is increased: this, however, as already shown, can only occur when it is of too great capacity. The stack, although tapering on the exterior, is internally nearly of one uniform area throughout; there being offsets at certain distances, according to the height and form. In erecting, every eight or ten courses should be built with hoop iron; when this is not done the stack frequently cracks, afterwards demanding the use of hooping on the exterior, which is unsightly.

At many large works a number of dwarf chimneys are erected, each of which is about a foot and a half or two feet square internally, and serves for three or four double settings. The area of a chimney compared with the number of benches leading to it is the main consideration, irrespective of the height.

Very recently Mr. Valon has adopted the use of a separate dwarf chimney to each bench of retorts, with beneficial results, as the temperature of the settings is maintained with greater regularity than by the ordinary method, whilst any leakage from the retorts is readily detected.

The ordinary chimneys in gas-works vary in height from 35 feet to 150 feet above the level of the ground; their cost for a given height depends mainly on their internal area and the nature of the foundation. The ground being favourable, the price of a square chimney, 35 feet high, with an internal area of 4 square feet, will not exceed £35. An octagonal or circular stack of 8 feet internal area, and 60 feet high, under the same conditions as the former, will cost about £85. A similar stack of 10 feet area, and 100 feet high, would be £180 to £200. Where there is no probability of a nuisance being occasioned by low chimneys, for the ordinary use of a gas-works they are not required to be more than 45 feet high.

CHAPTER VII.

RETORTS AND RETORT SETTINGS.

The evils of Iron Retorts—Clay Retorts—Brick Ovens and Brick Retorts—Means of repairing Retorts—Retort Settings—Form of Furnace—Iron Retort Settings—Method of setting one Cast Iron Retort—Setting of three Iron Retorts—Compound Settings—Radiation of Heat—Clay Retort Settings—Drawings—Settings of one, two, or three Retorts—Setting of three Retorts—Five Retorts—Elevations and Sections of various kinds—Brick Ovens and Retorts.

RETORTS.

FOR many years after the first establishment of gas-lighting, the retorts generally employed were of cast iron; but about 1820 clay retorts were introduced at Wolverhampton, and from there their use extended to Scotland, where during a considerable period they were countenanced to a limited extent; but only about the year 1852 was the attention of gas engineers generally directed to the advantages to be derived from them.

The evils attending the use of iron retorts are numerous. They are costly in themselves, which is increased by the expense of setting, principally occasioned by the use of fire-clay materials to protect them from the direct action of the fire. Iron retorts cannot be heated to the required temperature to obtain the full quantity of gas from the coals. Their duration is also very limited, averaging about six or eight months, each ordinary retort producing 600,000 or 700,000 feet of gas, whilst the average life of a clay retort may be estimated at two years and a half, and producing from 3,000,000 to 4,000,000 cubic feet of gas. In short,

F 2

the cost of iron retorts is estimated at 6d., and that of clay retorts at 1d., per 1,000 feet of gas produced. Moreover, the use of iron retorts is attended with another difficulty, arising from the formation of the carburet of iron on their exterior, which demands cleaning occasionally; and in this operation, a portion of the non-conducting material—the carburet of iron—lodges in some inaccessible places, and prevents the heat of the fuel in the furnace, penetrating to the coal undergoing the process of carbonization. Another evil is that the iron becomes changed in its nature, and loses its powers of conducting heat, which occasions a great expenditure of fuel for carbonizing. Besides these and other defects, care must be employed to prevent the retort attaining that temperature which would be destructive to it. Therefore, for these reasons, iron retorts are very rarely used at the present day, and then only in works of very limited capacity; nevertheless, the fact of their being occasionally employed, is sufficient for us to refer to them.

Iron retorts are useful in very small works, as in those supplying manufactories where the "make" is very irregular, and where they are required to "stand off" at intermittent periods. Under these circumstances the charge of coke is left in the retorts, the fire is banked up, and the damper closed, for the purpose of retaining the heat, until the retort may be again brought into operation at a short notice. They are also necessary for experimental purposes, although possessing the defect, that they cannot be worked at the heat most favourable for the development, of the full quantity of gas to be derived from the coal.

When in operation for any protracted period, iron retorts expand considerably, and after being worked some time and cooled down, a retort originally 7 feet 6 inches long will be found to have elongated about three inches. If this be put again into operation it will expand, but not in so great a proportion; however, it is not uncommon for a retort such as that mentioned, which has been repeatedly heated and cooled, to expand five inches in length. Therefore, when used, the ovens of these should be considerably longer than the retorts, otherwise the probability is that the front wall of the oven will be bulged out, with the risk of breaking the ascension-pipes—by no means an uncommon occurrence at one time.

When iron retorts are required for future use, previously to being allowed to cool down the carbonaceous incrustation in the interior should be removed; for, in the event of this being allowed to remain, the retort sometimes breaks in two halves, which is caused by the iron contracting in a much greater degree than the carbon. However, when they are worked at a very low temperature, namely, at blood-red heat as seen by daylight, the duration of iron retorts is considerable, as under these circumstances little incrustation of carbon exists on their interior, nor is any appreciable deposit of carburet of iron formed on their exterior; but these advantages are dearly obtained at the cost of the production of gas; as with this low temperature a yield of not more than 6,000 or 6,500 feet of gas per ton will be derived from the coal.

CLAY RETORTS.

The general adoption of clay retorts was very gradual, and to their use is undoubtedly mainly due the present great development of gas, alike for the purposes of lighting, cooking, heating, and numerous other domestic and industrial purposes. When first employed clay retorts were made from plastic fire-clay alone, when they broke into innumerable pieces, on being exposed to the degree of heat necessary for carbonization; and only after various repeated experiments and failures was the proper method of making them understood. At the present day they are formed of a compound of plastic clay intermixed with granulated burnt clay, and the greater the proportion of the latter in the compound, the more capable is the retort to withstand the action of the heat without cracking, which is the principal aim in manufacturing them. The clay for the manufacture of retorts is not required of a very high degree of refractoriness, as the temperature to which it is exposed seldom exceeds 2,200° Fah.

An objection which was formerly raised against the use of clay retorts is, that they are so porous as to permit the gas to escape. This, however, should the retort be of good quality, is erroneous, which any one may be convinced of by breaking one of them which has been in use for any length of time, when it will be found that the carbon has perhaps penetrated to the depth of half, or three-quarters of an inch, but shows no signs of having traversed the material. Generally clay retorts of good construction, when the pressure is very limited, are not more porous than those of iron, unless they are cracked or broken, which alters the case.

As regards the objection, also raised at one time, that clay is a worse conductor of heat than iron, no one will dispute this; but the opponents of clay retorts did not take into account the vast quantity of this non-conducting material which was employed for the purpose of protecting the iron retorts, nor did they consider the quantity of non-conducting material continually being formed on their exterior. If these points had been duly weighed, clay retorts would have had considerably less opposition.

Although the manufacture of clay retorts would appear a very simple process, there is a peculiarity of manipulation in preparing and tempering the clay and in constructing the retort, which, if not strictly adhered to, results in failure. In first-class fire-brick works a surprising amount of care is taken with the clay. This after being extracted from the mine is not considered suitable for the purpose until it has been exposed for many months, and sometimes years, to the action of the atmosphere, which acts chemically on it, and renders it suitable for the object intended.

There are three forms of clay retorts generally in use, the round, the D-shape, and the oval. The first is objectionable on account of the comparative limited area of the surface, and the irregular thickness of the charge of coal; the second is generally preferred on account of the uniform thickness of the coke derived from them; whilst in our opinion the oval form is the best. It is to be regretted that more uniformity of opinion does not exist, not only as regards the best shape of retorts, but also in their dimensions; as we are assured by a manufacturer who keeps in stock upwards of forty different kinds of the D-shape, that he is constantly requested to make other descriptions, in some cases varying only in the position of the bolt-holes, or perhaps a quarter of an inch in the breadth, or the height. On the Continent the shape most generally adopted is the oval of 21 inches wide and 15 inches high, and which we strongly recommend whether for a setting of one or more retorts; as this shape possesses the advantage of the facility of drawing of the round retort, and the layer of coke is about as uniform as when coal is carbonized in the D retorts.

But clay retorts cannot in most cases be worked advantageously without an exhauster to withdraw the gas the instant it is produced, in order to prevent it remaining under pressure, and exposed to the red-hot surface. Should the retorts be worked at a high heat and the pressure be considerable, in the absence of the exhauster, the heavy hydro-carbons are deposited in great abundance in a solid state within the retorts: at the same time deteriorating the value of the gas as an illuminating agent; generating a non-conducting material which obstructs the interior of the retort; and requiring more fuel for carbonizing.

Clay retorts, like those of iron, are of uniform thickness throughout, averaging about 2¼ to 2½ inches, except at the mouthpiece, which is made thicker for the purpose of sustaining the bolts. The mode of setting them is remarkably simple, requiring no guard nor shield tiles, and in some cases the arch over the furnace is dispensed with. The mouthpieces of clay retorts are precisely similar to those of iron, but their sockets and ascension-pipes are required to be larger; and they should never be less than 6 inches internal diameter, in order to avoid stoppages.

For attaching the mouthpieces to the clay retorts, the retort for a length of about 10 inches at the mouth is made of considerably greater thickness than the other part, and in it are formed a number of holes for the bolts, of about 1⅛ inch diameter, and 6 inches long. At the end of each of the holes is a square orifice sufficiently large to receive a nut corresponding with the bolt, which is made of ample length. The bolts are screwed at both ends, and when about to attach a mouthpiece, the retort is laid in a horizontal position; when, on the end being well wetted, the bolt-holes are then filled with cement or fire-clay in a plastic state, and each of their corresponding nuts is attached. The mouthpiece and the end of the retort are then both covered with a layer of about ⅜-inch of plastic fire-clay, intermixed with a portion of iron borings and sal-ammoniac, in the proportion used for iron cement. This accomplished, the mouthpiece is carefully placed in its position, when the nuts are attached and screwed up gently. After a time, as the joints become harder, the nuts are screwed tighter, and on the cement becoming dry, by the action of the iron it is rendered impermeable. This kind of cement is also very excellent for attaching the ascension and other pipes on a works, and offers the facility of being readily removed when desired.

At some works brick ovens, or brick retorts, are used. The distinction between the two terms is, that when only one or two large retorts are built in, and occupy the arch, it is called an oven; but when three or more of them are placed in the same arch they are called retorts. For both purposes special bricks are necessary of a form and size to suit the structure. Where there are several brick retorts in a bed they are required to be built before the arch of the oven is constructed. Each retort is formed on a centre, which is afterwards removed, and on filling up the wall spaces between the retorts, bolts are built into the wall, which secure a cast-iron plate embracing the whole of the retorts in the bench. The space between the wall and the plate is filled with fire-clay, or other suitable material; this effected, the mouthpieces are attached to the cast-iron plate. This system has been adopted for many years at the South Metropolitan Works with success. However, it was tried at The Gas Company's Works with the opposite result.

Brick ovens can be built within the arch of the oven, although for that object men used to the work are indispensable. It is a singular circumstance that engineers who adopt brick ovens generally maintain their superiority, regardless of the quantity of fuel they consume. We had some experience with Grafton's ovens some years ago, and although they were very durable, there was the great drawback of the extraordinary quantity of fuel they demanded. In our opinion neither brick ovens nor retorts are economical, for the simple reason that both of these are of much greater thickness than ordinary clay retorts, and consequently they must demand more fuel.

The principal requirement of good retorts is, that they shall not crack when in operation; and that such retorts exist is beyond doubt, but they demand an especial kind of setting, for if walls abut against them they must of necessity be broken.

One of the most common defects of clay retorts is the facility with which they crack when in operation, giving rise to a considerable loss of gas if due care is not observed. When a retort is coated with carbon an orifice in it is perceived by the brightness of the carbon covering it; and in a retort in a clean condition any crack will be observed by the bright streak it forms. In these and similar cases the defect should be remedied without loss of time, and for this purpose the best material that we know of is the cement made by Richardson of Birmingham. This is mixed with water to the consistency of mortar, and should the hole be large it should be stopped by a piece of fire-brick with the cement. Should the retort be cracked, it can be repaired by means of the "paddle," which consists of a rod of inch gun barrel six feet longer than the retort; on the end of this is coiled some rope yarn for a length of 9 inches, making a cylindrical pad of about 3 inches in diameter. When required for use the pad is well wetted, and a quantity of cement is placed thereon. It is then inserted in the retort, when by pressing the pad and cement against the crack, and turning the paddle round, the cement is forced into and closes the aperture. By these means most cracks or apertures are readily repaired, and the retort is immediately ready; fire-clay is sometimes used, but it does not adhere like the cement, besides the former often breaks away after being placed.

The price of a setting of clay retorts, including foundations, oven, furnace door and frame, ash-pan, fire-bars, buck-staves, sight-boxes, retorts, mouthpieces, two lids, ascension and bridge pipes, dip-pipes, and hydraulic main—in short, the bed complete, with all its accessories—is generally estimated at £15 per retort, so that a bed of seven retorts of average dimensions, or 21 × 15 by 8 feet 6 inches long, will cost about £105. The average durability of good clay retorts may be considered about two and a half years, during which time the expense for fire-bars, repairs to furnace, &c., will not exceed 20s. per retort. The duration of brick ovens in some works, is often four and even five years.

The arch of ovens once properly built will last several years. Taking down retorts, and replacing them with new ones, including labour, materials, &c., averages £6 per retort; so that replacing a setting of seven clay retorts would cost about £42. When double retorts are used, the same estimates per mouthpiece are applicable.

Retort lids are very commonly made of wrought iron, and stamped with a ridge to support the luting. They are considerably lighter than those of cast iron, which is their principal recommendation. Formerly considerable labour was occasioned by lifting off and replacing the cross bar and key to secure the door of the mouthpiece at each charge. This is now generally avoided by attaching the cross bar with a hinge joint to one of the arms of the mouthpiece. By this arrangement all that is required when drawing a charge is to loosen the key, and allow the cross bar to swing on one side, and when closing a retort, the bar swings back into its position, is secured by the corresponding stud, when the key is screwed up.

ON RETORT SETTINGS.

The disposition of the retorts in the ovens, or the manner they are placed or set, is called the "setting," and the judicious arrangement of this part of the apparatus in gas manufacture, is of the utmost importance; for on this mainly depends alike the economical production of gas, the use of the minimum quantity of fuel for carbonizing, and economy in labour.

Setting retorts comprises the construction of the ovens and furnaces; properly placing, supporting, and protecting the retorts; arranging the passages between them so as to equalise the heat throughout; and making the communication with the main flue; and to approach perfection in this, there are several points to be considered.

The foundations of the retort ovens should be solid and sufficiently massive to prevent the loss of heat at that part. In iron retort settings, all superfluous brickwork in the interior of ovens should be avoided, leaving only that necessary for the proper support of the retorts, and the proper protection of shields and fire-tiles to guard them from the injurious action of the excessive heat. All means to prevent the radiation of heat from the exterior of the setting should, so far as practicable, be adopted; for all heat lost unnecessarily from this cause is so much coke lost without a purpose. The openings or nostrils for distributing the heat from the furnace should always be amply wide. Many instances have occurred where the furnace has been at an intense degree of temperature, yet the retorts above could not attain an ordinary heat, on account of the passages or nostrils being contracted. An essential point also is to have complete control over the damper leading to the flue; for if this be too much open, and the draught strong, a great increase of fuel is necessary without any good result. Lastly, whilst due consideration should be had for the comforts of the stokers employed, all useless loss of heat in the retort-house should be prevented, and for this object the building should not have too many openings, as doors and windows; and when air-shafts or ventilators are constructed, these should be provided with valves, to shut or open, according to the weather or the season of the year.

The rules to be observed in setting clay retorts are, however, not definite, for whilst some engineers employ no brickwork in the interior of the oven, except that used for supporting the retorts, the stops, and the quarries which carry the retorts, which in our opinion is the proper system; other engineers place several transverse walls within the oven by which all the retorts are surrounded. We believe the necessity for these walls arose, in the first instance, from the imperfect manner clay retorts were at one time made, when they cracked, and the walls were introduced to keep the pieces in their places.

There are, however, other definite rules which apply equally to clay, or brick, or iron retorts; namely, inasmuch as the fuel used for carbonizing is generally coke, the furnace of the setting should be adapted for consuming it in the most advantageous manner. This is accomplished by making the furnace narrow at the bottom and of a good depth, in order that the air in passing, in its progress through the thick layer of fuel, is heated to a very high degree, and afterwards its caloric is distributed throughout the bench. Formerly, in building retort furnaces, the steam boiler furnace was copied, by presenting a large area for the passage of the air and placing the fuel in a thin layer. This system, although admirable for consuming coal where a slight current of air may be desirable to intermix with the carbon vapours, and where a certain quantity of heat of comparatively low temperature is required (as in the steam boiler), yet in the gas furnace, in which great intensity of heat with a limited supply of air are wanted, the deep and narrow furnace is, beyond all doubt, the most desirable.

The furnace bars are invariably of wrought iron, as cast iron is rapidly destroyed by the heat, and generally bars of 1¾ or 2 inches square are employed alike for the furnace bars, as for the bearers. An important point is that the furnace bars should project to the level of the front wall, as shown in Fig. 4, page 112, and other engravings, and they should be placed loosely on the bearing bars. It will be observed that a small space is left immediately beneath the door, through which a current of air is continually passing, which prevents the door frame from being acted upon by the heat of the furnace.

The arrangement shown is particularly well adapted for medium and small-sized works—indeed, for all works where the furnaces are clinkered from the firing-floor—as the smaller clinkers can be removed without opening the furnace door, by simply moving the bars and applying the rake; but for the usual process of clinkering, which, with moderately clean coke, that is free from iron, will be required once in twelve hours, the coke will have to be drawn from the furnace, when the clinkers are removed, for which object the loose bars offer great facilities. We have been very explicit on this matter, holding the opinion that it is the best description of retort furnace, and which we can recommend to the reader.

As the smaller settings of one or two retorts require comparatively a larger area than others of five, six, or seven retorts, no definite law of area can be applied under the different conditions; moreover, this is a subject on which there is considerable division of opinion. However, in accordance with our experience, for a bench of three oval retorts 21 × 15 × 8 feet long, we believe a furnace 5½ inches wide at the bottom, 36 inches long (that is, from the front of wall to end), and 10 inches high above the top of furnace bar with one fire-bar, is ample. For a bench of five retorts the opening at bottom will be required of 7½ inches wide, with two furnace bars each 39 inches long; and for seven retorts the same width, with the bars 42 inches long, will be ample.

A great want in gas manufacture is a kind of brick for that part of the furnace in immediate contact with the coke, which is the most vulnerable point of a clay retort setting; for whilst all the other parts, such as the retorts and their supports, will often last three and four years, the bricks in the immediate vicinity of the coke are eaten away very perceptibly in the course of a few months, and consequently the fireplace is increased considerably, with a large augmentation of the fuel account. The Ewell bricks are the best kind known to withstand the heat, and are generally used for those parts of a retort setting where the highest heat exists; but, unfortunately, they are of that soft nature that they are easily broken by the clinkering bar, and are therefore unsuitable for the lowest part of the furnace.

In the course of time, however, as the bricks wear away, by some engineers the sides of the furnace are patched up from time to time with fire-clay; but, generally the fire-brick, to the extent of 9 inches thick, is removed and renewed with new material. For this purpose the setting is put out of action and allowed to cool. The mouthpieces of the retorts, which are liable to be disturbed in the operation, are then strutted. This effected, the door and frame are taken down, and the brick-work in the front wall cut away, so as to allow the man to work. The burnt bricks of the sides of furnace are then cut out and renewed by others, which accomplished, the front wall is built up, when in a couple of days, by the plan adopted, the setting is again ready for firing.

IRON RETORT SETTINGS.

Figs. 3 and 4 represent the mode of setting one cast-iron retort in an oven, which, with a slight modification, is equally applicable for a clay retort. In Fig. 3 the bench is shown partly in elevation and partly in cross section, through the line B C in longitudinal section; F is the furnace, R the retort, P P P P are piers which support the fire-clay slabs S S, and on which the retort reposes. These slabs extend from the front wall throughout the whole width of the oven, but having an orifice at the end near the wall, as seen in Fig. 4. Immediately in the centre and on the top of the oven is a small flue, E, of about 5×5 inches, leading into the main flue, G. This small flue communicates with the oven by the orifice N, and near the main flue is the damper *d* to control the draught. When in operation the fuel in the furnace radiates its heat to the most immediate vicinity, whilst the currents of heated air and gases pass in the direction of the arrows up the end of the retort, and then along the top to the orifice N; it then enters the flue E, where it is controlled by the damper. The slabs S S are placed to protect the iron against the vivid action of the heat in the furnace; but in the event of a clay retort being set in the same oven, only the two slabs immediately over the furnace would be required; and if the retort were of doubtful quality it might be necessary to place some supports to retain it in the event of it breaking.

The simplest kind of setting of three iron retorts is represented in Figs. 5 and 6, page 113. Fig. 5 shows half the elevation, also half the section within the front wall; through the line A B. Fig. 6 is the longitudinal section. Immediately over the furnace is an arch, *a*, which extends throughout the length of the oven, for the purpose of protecting the retorts from the excessive heat of the fuel in the furnace. There are five transverse walls, *w w w* (Fig. 6), on which are placed a number of fire-slabs ex-

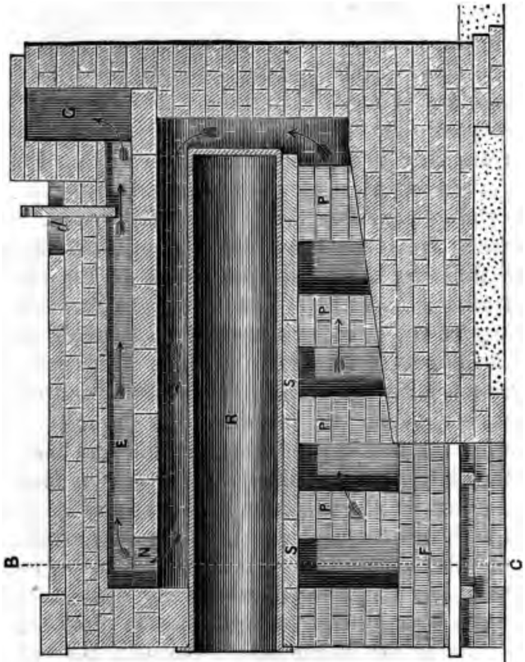


Fig. 4.

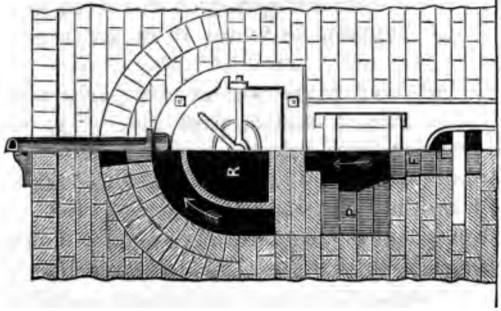


Fig. 3.

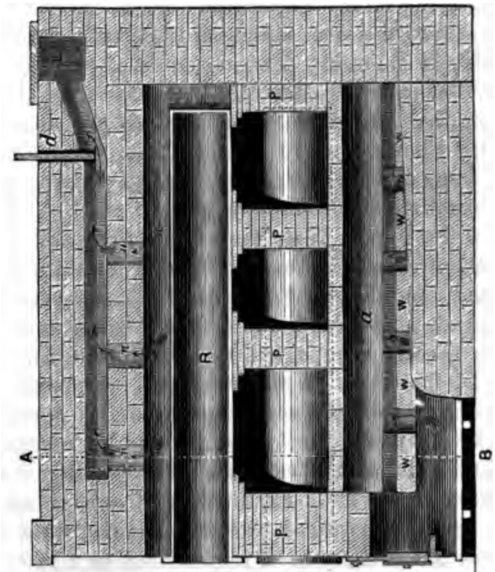


Fig. 6.

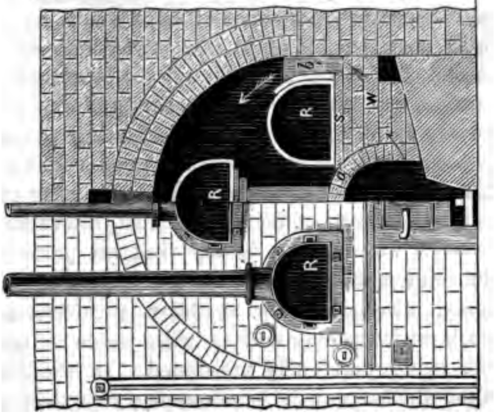


Fig. 5.

tending over the whole surface beneath the lower retort from the front to the back wall. Four nostrils are left on each side of the arch communicating with the openings by the side of the retort, for the current of caloric, as indicated by the arrows. Beneath these openings there are orifices in the wall which extend throughout, and are intended for clearing out any accumulation of carburate of iron that may collect. These slabs, S, on which are placed the two lower retorts, literally form the "bench," and serve to protect the retorts from the most violent action of the heat of the furnace; the curved fire-tile shields at the side answer the same purpose. To support these curved shields a brick on edge *b* is placed over each transverse wall. Three piers, P P P, each surmounted by a fire-slab, carry the top retort. In the crown of the arch are three nostrils, *n n n*, communicating with the small flue, which is in communication with the main flue L, but separated by the damper *d*.

This is the simplest of settings, and was adopted during many years as the most successful and economical. But had the great importance of the exhauster been understood, they would have been appreciated to a still higher degree, and enormous quantities of coke would have been saved which were permitted to flow away uselessly in its gaseous state. Unfortunately, this system is often imitated at the present day, as with a good draught and an open damper every facility is given for dissipating the coke to the atmosphere without attaining any good result; moreover, with an excessive draught and consumption of fuel, often the heats, instead of being advanced, are retarded.

It is almost unnecessary to say that all parts of the setting in immediate contact with the fire should always be of good fire-bricks, for at least a thickness of 9 inches, built with fire-clay and as thin joints as possible, the bricks being previously moistened. In the furnace, double that thickness will be necessary, placed in such a manner, that the furnace can be repaired as already stated, when desired. The furnaces should be constructed of the best bricks that can be procured. Some descriptions of Stourbridge bricks, and others called "Dinas" bricks, are reputed to be good for the purpose; but according to general opinion, to resist great heat the Ewell fire-brick is the best.

Some years ago a theory was adopted by a gas engineer, that the heat necessary for carbonizing with clay retorts was excessive, and that a portion of it as employed in the ordinary way was lost; hence it was suggested that the excess of heat of the clay retorts should be used to heat those of iron, which metal being a better conductor of heat would allow the caloric to pass freely to the coal under carbonization. This led to one or two patents, which, like many other inventions, have been only supported by the reputation of the parties most interested, who in this case pretended to be enabled to heat a bench of iron retorts of equal number and capacity as those of clay, with the "waste heat" from the benches of the latter. In addition to this various other plans were adopted, such as by placing iron retorts in the oven with clay retorts, the former being at the most distant point from the furnace. Or, in other cases, there were two ovens the one above the other; the clay retorts being in the upper oven were heated directly from the furnace, and the current was conveyed to the lower oven. And in some instances the ovens were set side by side, the clay retorts being heated by the furnace in the usual manner, from whence the heat passed into a setting of iron retorts; thus if we suppose seven retorts to be placed in each oven, the fourteen retorts would be heated by one fire.

Since the days that that theory was proposed, we have become more enlightened. We now know the value of keeping retorts, whether of iron or clay, at the proper temperature, in order to obtain a fair yield of gas from the coal. We also know that the supposed "waste heat" was nothing of the kind, simply because if that had been employed, the dampers would have been closed in the

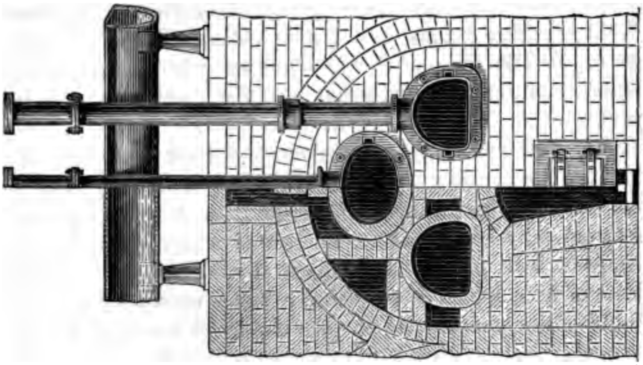


Fig. 9.

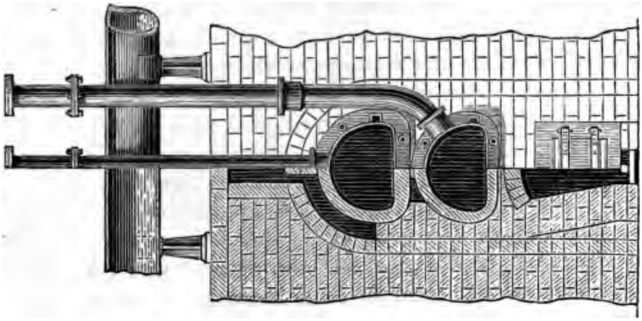


Fig. 8.

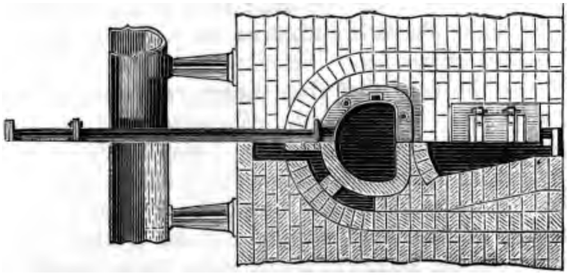


Fig. 7.

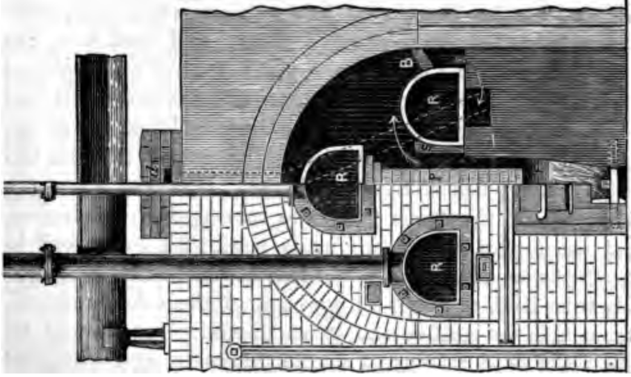


Fig. 10.

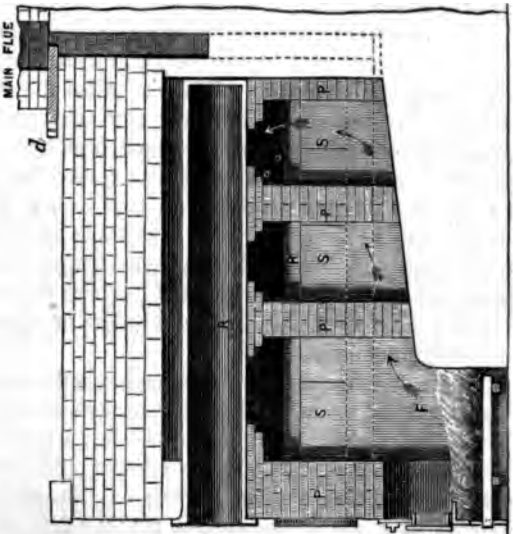


Fig. 11.

ordinary manner; whereas, instead of this being the fact, large orifices were made communicating the clay with the iron settings, and only by these means were they rendered in any manner effective. This was called the "combined setting," but instead of offering any advantages it had directly the opposite tendency, inasmuch as by it there was considerably more external surface exposed for the radiation of the caloric; and, when two ovens were used, rarely were the iron retorts of a suitable temperature for carbonizing. However, this system struggled for a few years, and naturally a low yield of gas was the result; but it is now numbered among the blunders of gas manufacture of bygone days.

And here another important question calls our attention, namely, that of radiation of heat from the benches of retorts. This at first sight may appear to be but a trifling matter, which error, however, we hope to dispel, and for that purpose will mention a case bearing on the subject, which occurred at a gas-works abroad making fifty millions per annum, where the consumption of fuel was excessive—about 70 per cent. of the coke produced. The retort-house was the hottest we ever entered, and on investigation we ascertained that the arches of the furnaces, which were only 4½ inches thick, were left as they were built, with about 9 inches of sand over them; and such was the temperature of the sand that a piece of wood when placed in it was speedily charred. Besides this the front wall was of no greater thickness than the arch. Hence it was not surprising if the heat radiated to the extent to cause the extraordinary use of fuel mentioned. However, when the thickness of the front wall was increased to 14 inches, and the top of the arches made solid with brickwork to the thickness of 18 inches, the fuel account was diminished less than half, or about 32 per cent. of the coke produced. From this we gather the great necessity for having all the walls of a setting of ample thickness, and whenever beds out of use adjoin those in action, then in order to prevent loss of heat by radiation the former should be bricked up. In short, caloric is a commodity of value, and, although not so tangible, should be regarded with the same degree of care as coal itself.

SETTINGS OF CLAY RETORTS, BRICK OVENS, AND BRICK RETORTS.

With the introduction of clay retorts some modification was made in the manner of setting them, but according to our experience they were originally set in a manner identical with the iron retorts, Figs. 5 and 6, with the exception that the side shields and the slabs were dispensed with.

Figs. 7, 8, and 9, page 116, represent half elevations and sections of settings of one, two, and three clay retorts as erected by some engineers. According to this system an arch is built immediately over the furnace in order to protect the lower retorts, whilst the interior is so arranged that the current of heated air is compelled to pass at least twice along the oven. The method of retaining the arch is adopted by the majority of engineers, but in our opinion it is unnecessary, and that its use contributes to a great expenditure of fuel.

The simplest setting of clay retorts with which we are acquainted is represented by Fig. 10, half in elevation and half in section, Fig. 11 being the longitudinal section. This is unlike the setting of three iron retorts already described; for instead of the caloric passing off at the top of the arch, it is caused to pass towards the back of the bench, where there is an opening in the stop B. It then returns to the front of the setting, enters the flues under the bottom retorts, and then passes up the flues at the back indicated by dotted lines and thence off to the main flue, at the entrance of which there is a damper; which, we cannot repeat too often, is of paramount importance in a retort bench. On the introduction of clay

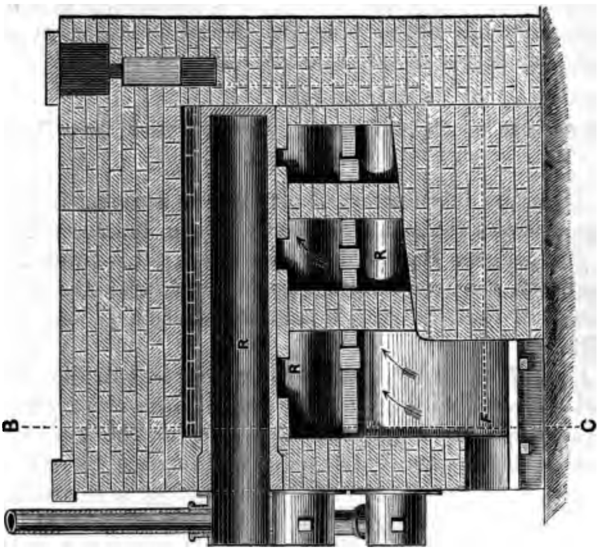


Fig. 13.

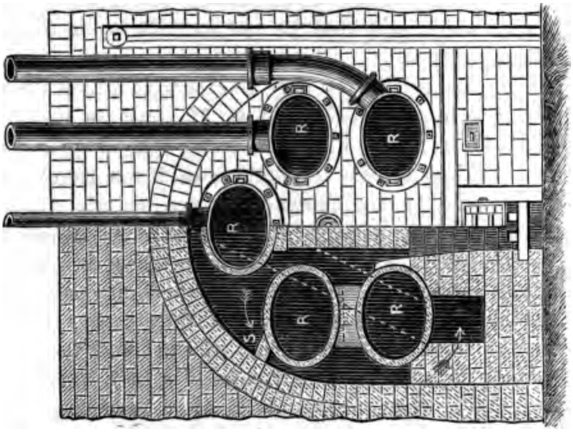


Fig. 12.

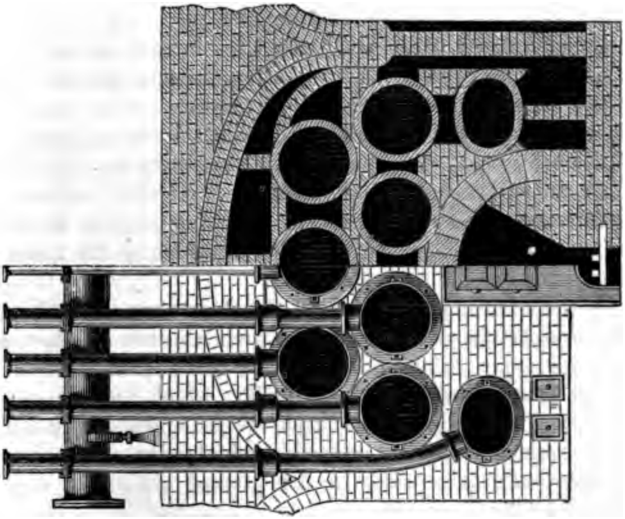


Fig. 15

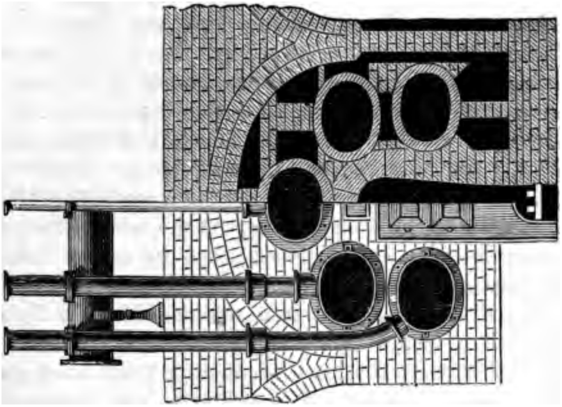


Fig. 14.

retorts, in consequence of their liability to crack, and in order to prevent the pieces of the retort becoming detached, as already stated transverse walls were introduced, which, in addition to causing serious obstructions to the passage of the caloric, were productive of another serious evil, as when these walls abut against the retorts, by the expansion of the brickwork the latter must of necessity crack. But when retorts have been set isolated from the brickwork we have seen them taken down after long service in one entire piece, which could never be done when the transverse walls are built against them.

By the setting just described, the retorts are exposed to the direct action of the heat, and carbonization is effected with a low percentage of fuel. For this object, however, retorts of extraordinary good quality, which are not susceptible of cracking with the heat, are indispensable, and if these could always be assured, undoubtedly a complete change would take place in the present method of constructing retort benches.

It may be remarked, however, that a great diversity of opinion exists concerning the subject under consideration, for, as will be shown, some engineers approach very nearly the system already described; whilst others place a number of transverse walls within the oven and abutting on the retorts; and others again adopt the middle course, by having small separations of brickwork in order to cause the current of heat to make a circuitous route, by which it is supposed that the caloric is retained within the oven a longer time and becomes more effective.

It has been pretended that by the introduction of transverse walls in the ovens to support the retorts the passage of the heat is not impeded; but to refute this error we have only to refer to the shield tiles and the slabs employed to protect the iron retorts, which do their duty effectually; hence it follows that if a non-conducting material impedes the heat in one case it must also do so in the other. Therefore it is evident that these walls do obstruct the heat, but if reliable retorts could be assured they ought and should be dispensed with. In some instances, however, transverse walls are employed to divert the passage of the caloric in order that it may make a more circuitous route and be retained longer in contact with the retorts. We hold the opinion that much of this is not productive of any good results, and particularly as, according to some of these systems, the current of caloric leaves the setting at the very hottest points, and of necessity under these conditions it must carry heat away from the retorts.

Fig. 12 represents a setting of five oval retorts, shown half in elevation and half in section, through the line B C of longitudinal section Fig. 13. This resembles the setting of three retorts on page 117, the principal difference consisting in the upper side retorts being placed on the lower ones, and supported by three saddle-pieces, the whole of the space between the two retorts being closed as seen in longitudinal section. At the side of the upper side retort is a stop, s, which extends from the front wall to within a foot of the back. When in action, the heat acts directly by radiation, and as there is no obstruction offered to it, we believe it must be highly effective. The current of caloric passes to the back of setting, returns by the orifice at the end of the stop by the side of the two retorts, and then enters the flues under the bottom retorts, and from there passes to the vertical flues shown in dotted lines in Fig. 12, and partly in section in Fig. 13.

This simple setting is in use at some works in the North, but they can only be employed where the retorts can be well relied on. With good retorts this mode of constructing benches should become general.

On page 121, Fig. 14, is shown a method of setting five retorts differing materially from Fig. 12. In this, as in all the other settings hereafter referred to, we find the arch adopted over the furnace. The various flues shown are for conveying the current of caloric backwards and for-

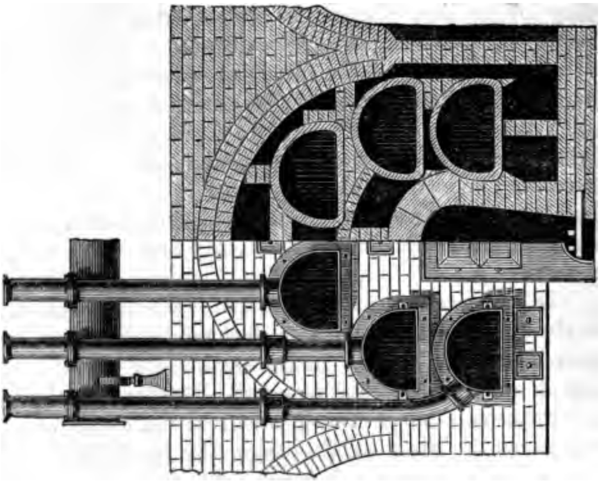


Fig. 17.

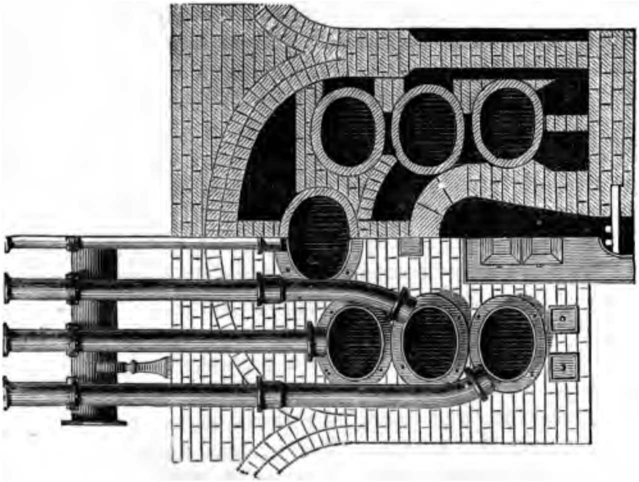


Fig. 16.

wards through the oven, so as to retain it as long as convenient in contact with the retorts. On the same page is also given the half section and half elevation of a bench of nine retorts, as used at large works.

Similar views of settings of six and seven retorts are given in Figs. 16 and 17, and in presenting these drawings, which are obtained from different sources, we give the ideas generally entertained on the subject in question, although, according to our opinion, every facility should be given for the diffusion of the caloric as in Figs. 12 and 13, and only by these means can strict economy in the fuel for carbonization be obtained.

In setting retorts, as in most other questions connected with the manufacture of gas, engineers are not decided on the number of retorts that should be placed in works of any given magnitude. And although for small works, where the production of gas admits of no choice, yet in medium and large sized works we find in some instances settings of five retorts are preferred, whilst in others six, seven, eight, and even ten retorts are placed in a bed. Nor is this diversity of opinion confined to the number of retorts, but it applies also to the mode of conducting the caloric. In some instances this has to make a circuit of four times the length of the oven before reaching the main flue, which by some is considered the perfection of setting.

Here we would advise any manager who experiences any difficulty in heating the retorts uniformly to the required temperature, and at a moderate expenditure of fuel, either to avail himself of the services of professed retort setters, who are to be found in several parts of the kingdom; or to obtain good working drawings of settings, which are to be procured from gas engineers, or from some manufacturers of fire-clay retorts. The amount of loss incurred by indifferent settings is beyond belief.

Brick ovens and retorts were used at several works on the Continent long before clay retorts were introduced.

These ovens were generally made to contain about ten cwt. of coal. They were charged with the shovel, and being directly over the furnace, which was of large dimensions, they were always readily maintained at a good heat; indeed, common defects with them were, the high temperature, the accumulation of carbon, and they were often quickly burnt through, which made itself evident by the brightness of the carbon covering the orifice. For reasons already given, we firmly believe that brick ovens cannot be employed with economy by any gas company.

But that brick retorts may be more successful we have a proof at the South Metropolitan Works, where they are, and have been, generally employed for many years. Brick retorts are sometimes used at large works in the depth of winter during the heavy lighting, on account of their offering the facility of being heated and let down without any material injury by cracking. This appears to be one of the great points of advantage, arising from the numerous bricks of which the retort is composed; and thus any expansion or contraction occurs over all of the numerous joints, so that only the most minute interstices exist, which are stopped by the first charge of coal.

However, brick ovens or brick retorts require men who are accustomed to the work to build them; hence, under these circumstances, they cannot be of interest to the general reader.

Our pages are unsuitable to describe all the details of a setting of retorts. We have, therefore, limited ourselves to the drawings presented.

CHAPTER VIII.

THE HYDRAULIC MAIN AND VALVES.

The Advantages of Hydraulic Joints—The Object of the Hydraulic Main—Dimensions of, and how it should be placed—Valves—Hydraulic and Slide Valves—Various Kinds of Valves.

THE hydraulic main constitutes the first application in the process of gas manufacture of that beautiful contrivance called the water-joint. It is this contrivance which enables the chemist to store and confine his gases in the receivers of the pneumatic trough, and thus by the use of denser fluids, such as water and mercury, to imprison the most volatile forms of gaseous matter in a mode which, for delicacy and subtilty, infinitely excels every contrivance of mere mechanical fitting. This valuable principle of sealing up the aëriform fluids by means of denser fluids, through which they can pass in one direction but cannot return in the other, is applied to the lutes of the purifiers, to the gas-holder, and, in fact, in every one of the appliances connected with the collection, storing, and distribution of gas. At present it may be sufficient to point attention to the value of this property derived from the different densities of fluids, which gives both to the chemist and the manufacturer a power over the aëriform bodies, which they would in vain strive to obtain by any other means.

The apparatus in question serves the purpose of a series of hydraulic valves for all the retorts, and if, in the early years of gas-lighting, such a contrivance had not existed, each ascension-pipe would have had to be provided with a separate valve, or tap, occasioning considerable labour to shut and open them every time the retort was charged. In addition to this, the risk and loss would also have been very great.

The hydraulic main is self-acting, beautifully simple in its construction, and, with the least care, accident or loss from it is almost impossible. It consists of a tube or trunk, sometimes of cast, but usually of wrought, iron, varying from 12 to 24 inches diameter, extending the entire length of the retort ovens, and, when made of cast iron, it is generally about ⅝ of an inch in thickness.

Cast-iron hydraulic mains are generally of such a length as to reach over one bench only, and the joints are made with bolts and nuts and cement, or with hempen gasket, in the usual manner. In old works the hydraulic main is often a circular tube, but in modern works the D-shaped main is usually employed, with the flat side upwards. Wrought-iron hydraulic mains, however, on account of their lightness and strength, have recently superseded those of cast iron. They are made of larger diameter and in longer lengths than the others, and have the further advantage of being to an extent flexible.

The hydraulic main when first put into action is supplied about half-full with water; but in the course of operation; the tar passing with the gas is soon deposited in it, displacing the water; thus the tar evolved in the carbonization speedily becomes the sealing liquid.

The end of the dip-pipe is immersed to a depth of one inch in the liquid in the main, and during the process of distillation, the gas passes from the retorts up the ascension-pipe, through the bridge-pipe, down the dip, bubbles through the liquid into the space above, and from thence issues to the apparatus for purification.

Each of the pipes thus dipping into the tar of the hydraulic main freely delivers the gas produced in its own *retort,* and effectually prevents its return. However numerous may be the pipes dipping into the liquid, whether they contain gas or not, and whether the retorts are working or otherwise, it is impossible, under ordinary circumstances, that any gas once arrived above the surface of tar in the main, can return back again, as each pipe is hermetically sealed by the tar.

The length of the dip-pipe, with the part of bridge-pipe to bridge, should not be less than 2 feet 6 inches. It is obvious that the pressure of gas from the working retorts will force the tar up a short distance into the dip-pipes of those benches which are out of action. From this cause, however, no inconvenience is likely to be experienced; but in the event of any obstruction occurring in the works, and the gas having no other means of escape—should the dips be too short, and unconnected with the bridge-pipes, as when under repairs—the gas would issue from them. As the hydraulic main is generally half-full of tar, its diameter must be so regulated that the tar forced up into the dip-pipes of the retorts out of action will not so far diminish the depth in the main as to unseal them, because this would simultaneously unseal every one of the dip-pipes, and the gas would immediately escape from the main.

Sometimes each length of the hydraulic main is provided with a partition, the top of which is level with the surface of the fluid; the object of this is to maintain that surface continually at the same height in every part of the main. Of course where so much depends on the effective sealing of the dips, every care must be taken to fix the hydraulic main in a perfectly horizontal position from end to end.

Formerly it was customary to take the gas off from the top of the hydraulic with the view of separating that from the tar as rapidly as possible; but the present method is to allow the gas and tar to escape together from the end of the main, by which means it is assumed that some of the impurities of the gas are absorbed by the tar.

The hydraulic should always be placed at some distance above the stack of retorts, at least twelve inches, in order that the tar within may not be heated to any great degree. By placing the hydraulic directly on the stack, as sometimes done, it is literally converted into a tar distillery, and in the course of time a thick coat of pitch is deposited. But by having the main as described some distance from the stack, from our experience during several years no important deposit takes place.

VALVES.

There are two kinds of valves used generally in gas-works, namely, the hydraulic, in which a column of water obstructs the passage of the gas, and the slide or surface valve, which stops the flow of gas by the close contact of accurately planned metallic surfaces, the contact being preserved by the action of a spring or other means.

The hydraulic valve is now rarely used in works, and when employed the gas is either altogether shut off, or the supply is entirely free; while the slide-valves are generally used for all the various apparatus, as well as in the street mains, and are of great service in stopping the flow of gas when a part of the main is undergoing repair.

Figs. 18 and 19, drawn on a scale of $\frac{1}{20}$th of the full size, show two kinds of hydraulic valves.

In Fig. 18, C is a cast-iron cylinder, for 10 or 12 inch mains, usually about 2 feet 3 inches long, and 14 or 16 inches in diameter; the other sizes being increased or diminished accordingly. The top of the cylinder has a perfectly air-tight cover with a stuffing-box, through which works the rod D. The cylinder contains water or tar to the level *a a*, or about a foot in depth. The gas passes into this cylinder, through the pipe A. The outlet-pipe B, through which the gas passes off to the mains when the communication is open, has its orifice about 3 inches above the level of the tar; E E is an inverted cup which covers the mouth of the pipe B, and can be raised when required by means of a pinion working into the rack on *the rod* D, or other suitable means. It is evident when the cup is at the bottom and immersed in the water, as shown, the gas is hermetically sealed and prevented from entering the pipe B, unless the pressure be sufficiently great to displace the tar and cause it to overflow into that pipe. In which case the gas would escape, but the depth of 12 inches is usually sufficient to prevent this, and to afford a most effectual seal. On the other hand, it is evident that when the inverted cup E E is raised above the surface of the tar, the gas will flow uninterruptedly from the gas-holder through pipe A, and thence into pipe B, which takes it off to the main. This kind of valve is extremely simple and efficient, the chief objection to it being that the outlet and inlet pipes are at different levels, an objection which does not apply to the next kind to be described.

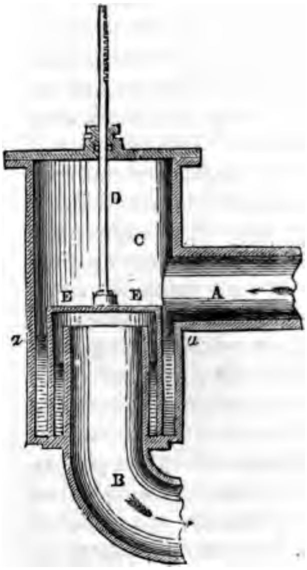


Fig. 18.

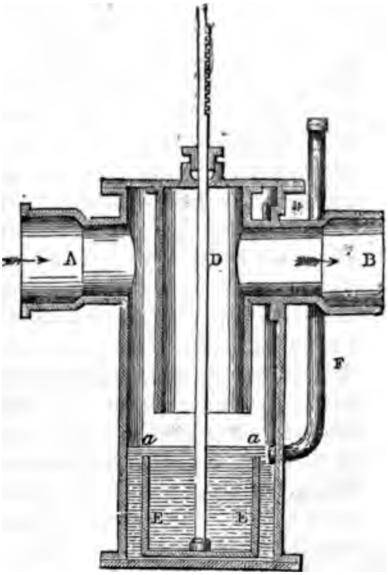


Fig. 19.

Fig. 19 is the section of a valve which is sometimes used in works, and has the advantage of acting as a receiver or syphon, to contain the tar or water, condensed from the gas in its passage.

The outer cylinder is about 2 feet 6 inches long, and about the same diameter as the valve last described, provided as before with an air-tight cover and stuffing-box, through which the rod D passes: A is the inlet and B the outlet pipe, both on the same level; E E is the movable cup, not inverted in this case, but entirely immersed in water or tar when at the bottom of the cylinder, and remaining full of the liquid when lifted up by the rod D to close the open end of the inner cylinder. The inlet-pipe A opens into the outer cylinder, and the outlet pipe B is connected to the inner cylinder. The water or tar should be a little higher than the top of the cup, namely, as high as the line *a a.* On the right-hand side of the engraving is a small pipe, F, with a screwed top, through which the water of condensation is pumped when it reaches above the level *a a.* Bearing in mind that the inner cylinder is open at the bottom and side, the action of this valve will be readily seen. When the cup is at the bottom, as in the engraving, the gas passes freely from A into the outer cylinder, then up through the inner cylinder, and goes off by the pipe B. When the cup E E is raised, however, the lower edge of the inner cylinder rests on the bottom of the cup, and being of less diameter than the cup, there is an annular space of water all round, equal in depth to that of the cup; this water effectually prevents the gas from passing through it to the outlet-pipe. The dimensions of the inlet-cylinder will depend on the diameter of the main to which the valve is attached, free space being left, inside and outside it, as may be readily understood.

When this kind of valve is used, where it would be inconvenient to have the rod D raised by means of a pinion, the cup is raised by another contrivance. The rod in this *case has a* thread cut on it, which works in a screwed nut forming part of a cross handle; thus when the handle is turned, the cup, being at the same time prevented from revolving, is raised by the screw until it attains such a position as to seal up the bottom of the inner cylinder. In small valves the rod is lifted by hand.

Hydraulic valves are now only used in gas-works, and never in the streets. They have the advantage of not being liable to leakage like some slide-valves, and shut off the gas very effectually; but they have the disadvantage that an accidental excess of pressure renders them useless.

Figs. 20 and 21 drawn on the same scale as the preceding show sections of the usual form of slide-valve, which possesses the quality that the supply of gas can be controlled by it with all facility.

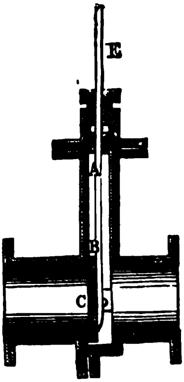


Fig. 20.

In Fig. 20, A B is the valve case; C is a circular iron disc attached to the rod E, which works through a stuffing-box at the top of the valve case; D, Fig. 21, is a spring which presses on the disc C, and causes it to be in perfect contact with its seat when in operation; the disc is very accurately turned in the lathe, and the rim of the pipe is also truly faced, as well as the part A B, against which the disc presses when raised so as to open the communication between the pipes. It is evident that when the disc is placed as shown in the engraving, the passage of the gas is stopped, and when raised by means of a pinion working in a rack cast on E, the passage can be entirely opened. When used in gas-works the disc is worked either horizontally or vertically, as shown in the engraving, but

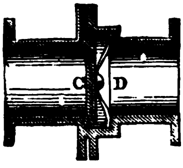


Fig. 21.

when employed in the streets the rod E is worked horizontally by means of a key fitting the axle of the pinion; in this case Fig. 21 becomes a sectional elevation, and the disc moves laterally instead of vertically to open the communication between the pipes.

Another kind of valve has come into use in gas-works during the last few years: in which a disc similar to that shown in Figs. 20 and 21 is pressed by a screw upon a faced rim, and when the screw is tightened the contact is so perfect as to prevent the slightest escape of gas. On the screw being relieved, the disc may be raised so as to afford any required opening for the flow of the gas: the screw may be placed either horizontally or vertically. This kind of valve is, perhaps, more correct and certain in its action than the spring slide-valve.

There are various other valves in a gas-works which either partake of the hydraulic or the slide. For instance, the hydraulic central valve, formerly very commonly applied to the combination of purifiers as invented by Malam, is a very useful and efficient apparatus. Indeed, in the gas-meter each inlet and outlet to the various measuring chambers is neither more nor less than a hydraulic valve. On the other hand, the slide-valve is applied to the central valve of purifiers; it is applied in the dry meter, and the ordinary tap is nothing more nor less than a slide-valve.

Other apparatus in a gas-works have a valve of another description entirely, that is the cone or plug-valve, which is met with in the governor, the inlet of the meter, and in some forms of valves employed for changing the communication between one apparatus and another or used as a by-pass.

Mr. Anderson has adopted a modification of the plug-valve tap, having three or four ways, which valves can be fitted to purifiers, or as a by-pass to the apparatus in a works, when one of them fulfils the duty of three or four slide-valves.

CHAPTER IX.

THE EXHAUSTER.

Its Object—Various kinds of Exhausters—Beale's Exhausters—Körting's Exhauster—Effects of excessive Exhaustion.

As already observed, when gas is submitted to a heavy pressure within the retorts, and the temperature is elevated, a portion of the hydro-carbons of the gas is deposited in a solid state in the interior of the retorts; and the amount of this deposit is dependent on the degree of pressure and temperature, to which the gas is exposed in the process of carbonizing. Besides this, as in ordinary working, there are always some slight leakages, which are augmented with heavy pressure, it is desirable, therefore, on these and other accounts, to exhaust or withdraw the gas from the retorts as speedily as possible after it is produced, so that it shall not be subjected to those influences.

For this object various apparatus are employed, called exhausters, which are actuated by steam, or gas power. These are constructed in different ways, either similar in action to an ordinary pump, or a rotary machine, or a modification of the gas meter, or one or more gas-holders working in tar, which are elevated and depressed by an engine; by either of which apparatus the gas is exhausted from the retorts and expelled to the holder. There is also an apparatus called Körting's exhauster, which requires steam only to render it effective.

In this apparatus, like in most matters connected with gas-lighting, engineers are divided in opinion as to the best kind for the purpose. Therefore, with the various ideas concerning it, it will be sufficient for us to say that the exhauster most commonly in use is that called Beale's. This machine was in its earliest form intended as a rotary steam-engine, but failing to meet the necessary requirements in this respect, it was in the course of time applied as an exhauster for gas.

This exhauster is represented in the annexed figure, 22, and consists of an outer cylinder, having the pipes for the inlet and outlet of the gas as indicated. To the shaft, which is placed excentric to the cylinder, is attached a smaller cylinder, in which a sliding piston is adjusted in such a manner, that its sides rub continuously against the ends of the cylinder, whilst its ends are in constant contact with the periphery. Thus, as the shaft is caused to revolve by motive power, the gas is drawn in or exhausted at one side and expelled from the other side of the piston, as indicated by the arrows. The general application of this exhauster is sufficient guarantee of its excellence.

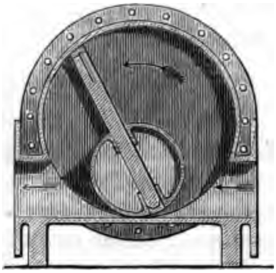


Fig. 22.

A form of exhauster consists of one, two, or three bells or gas-holders working in tar, having suitable clack-valves, on their inlet and outlet pipes; which bells are connected to a common shaft, with cranks corresponding with the height of the bells. The shaft is actuated by motive power, and causes the bells to receive and deliver, or in other words exhaust, the gas at each revolution. Another kind is similar to an ordinary pump, which at each stroke receives and expels a certain quantity of gas according to its capacity. Of these there are different systems; but the simplest is generally the best and cheapest.

And again, without pretending to indicate all the forms *of this class of* apparatus, we may refer to the steam exhauster of Messrs. Körting Brothers. The action of this apparatus will be understood by referring to the annexed diagram, Fig. 23, in which is represented the main *n n* proceeding from the condenser. Within this is a funnel, *m m*, and connected to the main is the small steam pipe *s*, which is bent as represented, and terminates with a very small orifice. The action is as follows:—The pipe *s* being in communication with a steam boiler, in which for economical working the steam should be at a pressure of about 45 lbs. to the inch; and supposing the main to be connected to the retorts in operation, the steam, on passing in the direction shown by the arrow, enters the smallest part of the funnel, and by its impulse, exhausts the gas from the point *a*, and expels it to the point *b*, as shown by the arrows.

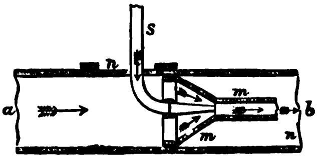


Fig. 23.

When practically applied, this instrument has the appearance of the continuation of the main, although of somewhat enlarged external diameter, and contains three or more of these funnels, the one placed within the other, but leaving a space for the admission of the gas at their peripheries, which is expelled at their ends as already shown. Connected with this form of exhauster are the means of regulating it according to the variable quantity of gas produced. It is also provided with a pressure-gauge, by which its action is known. These apparatus are very simple, and have met with considerable success, although we have heard that by their use, a considerable quantity of pitch is deposited in the pipes which eventually obstructs the passage of the gas. The expense attending them consists in converting about 2½ quarts of water into steam of the pressure stated, for each thousand feet of gas produced.

The exhauster should be placed immediately after the condenser, and be provided with a pressure-gauge, in direct communication with the interior of the hydraulic main. On the depth the dip-pipes are immersed in the tar of the hydraulic main being known—then by observing the gauge the pressure within the retorts is ascertained. To explain this, let it be supposed that the ends of the dips are exactly one inch under the tar. If now we imagine the exhauster to work in such a manner as to indicate "level gauges" on the exhauster-gauge, then there will be a pressure of one inch within the retorts.

It is highly desirable to work the instrument in question to the proper extent in order to counteract the effects of small leakages, as well as the high temperature of the retorts; but at the same time an undue degree of exhaustion should be carefully avoided, as by it, air may be drawn into the mains and intermix with the gas as produced; and according to various experiments only 1 per cent. of common air, intermixed with gas, diminishes the illuminating power no less than 6 per cent. With an admixture of 45 per cent. of air combined with gas, no light whatever is obtained from the compound. The detrimental effects of excessive exhaustion are clearly illustrated by the preceding; and although frequently it is asserted by prejudiced persons, that gas companies wilfully exhaust air for the purpose of augmenting the volume of the gas, the absurdity of the statement is clearly demonstrated by the facts given. Moreover, in addition to the production of a *quantity* of gas, the consideration of its *quality* is forced on engineers and managers, not only by Acts of Parliament, but also by more forcible reasons, namely, the interest of the companies they represent.

In all well-conducted works of medium size and of large capacity, there should always be an exhaust register in connection with the exhauster, in order that its operations may be indicated during the whole of the twenty-four hours. This apparatus is very similar to the pressure regulator hereafter referred to.

CHAPTER X.

THE PURIFICATION OF GAS.

The Temperature of Gas—The Condenser—Various kinds of Condensers—The Washer and Scrubber and their object—The Washer—The Scrubber—Wet-lime purification—Dry-lime purification—The central Hydraulic Valve—The dry central Valves—Oxide of iron purification—How to ascertain the value of oxide as a purifying agent—Sulphate of iron and lime purification—Tests for ascertaining the purity of Gas—The Sulphur Compounds.

THE CONDENSER.

HAVING described the different classes of coal, the various apparatus employed in carbonizing and producing gas, we now come to the purification; by which is meant the process of eliminating those constituents of crude gas that would be prejudicial to the comfort of the inhabitants, as well as to the furniture and ornaments, of dwellings where it might be consumed. As already observed, these impure constituents are ammonia, sulphuretted hydrogen, carbonic acid, bisulphide of carbon, and other compounds of sulphur and carbon.

The purification of gas may be stated to commence the moment it enters the hydraulic main, where it deposits some of its tarry matters, and there is ample reason for believing, as represented elsewhere, that a portion of the rich constituents of the gas is absorbed by the tar at that point, the remedy for which has already been suggested.

As the gas issues from the retorts, it is delivered in very minute vesicles or *small* tar bladders, and the first operation is to break these vesicles and liberate the gas. The apparatus invented by Pelouze and Audoin accomplishes this most effectively, but it is said that the process also diminishes the illuminating power of the gas by depositing the hydro-carbons, which we believe to be the reason why the apparatus has not been adopted in the United Kingdom. The method generally applied to break these vesicles is by causing the crude gas to pass through a great length of pipe, when, by the friction in passing, the numerous vesicles are broken, thus liberating the gas; and by the diminished temperature the vapours are *condensed* into the liquid state—hence the application of the term *condenser*.

The temperature of the gas as it issues from the coal averages about 160° or 180° Fah., unless the charge is very protracted, and continued after the coke becomes red-hot, when it is augmented. The first operation in the purification of gas has just been described, by which the ammoniacal liquor and tar are condensed, and conveyed to the receptacle intended for them. At one time it was the aim of some engineers to condense these vapours as rapidly as possible, and in some instances to a very low degree of temperature; but modern experience teaches us that both these systems are wrong, as by the former, naphthaline is produced, and by the latter, a portion of the volatile hydro-carbons of the gas is deposited with the tar, and the gas impoverished.

The process of condensation, according to the most approved system, is effected by placing the condensing pipes with a slight incline to the horizontal position, along or around the interior, and afterwards extending for a considerable length to the exterior of the retort-house; and in most cases the tar and gas are allowed to flow together through these pipes, with the object of profiting by the absorptive action of the tar, for the impurities sulphuretted hydrogen and carbonic acid. However, against *this advantage* should be weighed the absorptive action of the tar for the hydro-carbon vapours, and these, once absorbed, are only recovered by the operation of distillation.

Besides the system of condensation mentioned there are various other apparatus for the purpose. The one which is the most generally used consists of a series of vertical pipes attached to a cast-iron box or chest at the bottom, connected in pairs by semicircular bends at the top and called the "air condenser." This chest has a series of divisions, which are sealed by liquid placed therein, so that the gas in its transit has to pass through the whole series of pipes, as in the apparatus already described. Thus the pipes by their contact with the atmosphere radiate the heat from the gas, which being in consequence cooled, deposits the vapours as liquid in the form of tar, and water saturated with ammonia, generally called ammoniacal liquor. This condenser in warm climates is sometimes used with an application of cold water on its exterior in order to increase the cooling effect.

Fig. 24 shows a cross section, and Fig. 25 a longitudinal section of a vertical air-condenser, with the air-pipes attached to the iron-chest, which is charged with water to the line *a a*. The longitudinal section Fig. 25 shows that the chest is divided transversely into compartments, each of which contains two pipes in communication with each other. The cross section represents the chest divided throughout. Thus by these means, with the aid of the liquor in the chest, the pipes are connected in pairs, whilst as shown in Fig. 24 a connection is made between each pair of pipes in succession by the semicircular bends.

The action may be readily understood by referring to Fig. 24, where the gas on entering the pipe *b* passes the semicircular bend and descends pipe *c*, and enters the compartment beneath, where it passes into another vertical pipe and travels in the opposite direction to that marked by the arrows.

Thus the gas is caused to pass through all the pipes in succession, which radiate the heat to the surrounding atmosphere, and the vapours are condensed.

Another form of air-condenser, varying slightly from the preceding, which has become very general in large works, consists of an iron chest similar to that described, *but* of much greater dimensions, surmounted by a series *of vertical pipes* of large diameter, in which are enclosed

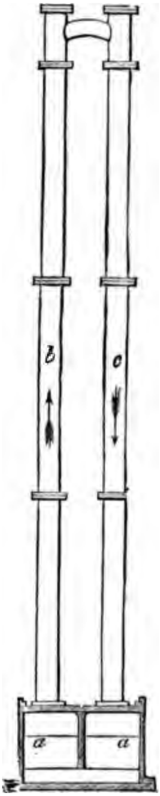


Fig. 24.

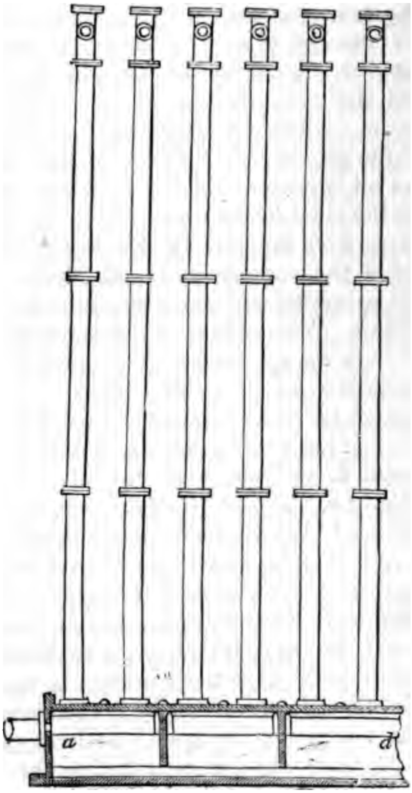


Fig. 25.

others considerably smaller, each pair forming an annular space, and through this annular space the gas to be condensed passes. The interior of the inner cylinder being open to the atmosphere allows a current of air to enter below. This, becoming heated, ascends, causing a draught or current, and carries off the heat; to which circumstance the superiority of this system is stated to be due. In addition to the concentric pipes, there are others which communicate the various condensing columns with each other, and so complete the apparatus. With this apparatus there are means of controlling the quantity of air according to the requirements.

Another kind of condenser, which is extensively used in large works, is formed of two vertical rows of pipes placed at a slightly inclined position, each row consisting of five or six tiers, varying in length according to the magnitude of the works. These are connected together at the two ends by suitable bends, and are all supported by an iron framework in such a manner, that as the gas enters at the uppermost point, all the condensed liquids flow throughout the whole length of the pipes in contact with the passing gas. It is the accepted opinion that by the friction of the gas passing through these condensers, the tar is eliminated, at the same time the ammoniacal liquor is effectively condensed; whilst the gradual action of the process does not deteriorate the quality of the gas, and tends to prevent the formation of naphthaline.

Lastly, the condenser, which was invented by John Malam, consists of a rectangular box or chest formed of cast-iron plates, put together with flanges, and having perfectly tight joints. Its interior is provided with a series of iron trays, containing each about two inches in depth of water, and so arranged that the gas, entering at the bottom of the chest, passes in succession over the surface of the water in each tray, and traversing the whole length of the chest ten or twelve times, passes off at the upper side. In the meantime a small stream of water enters at the top, and in its descent absorbs the ammonia, at the same time cooling and condensing the vapours in combination with the gas.

This condenser has long fallen into disuse, but we have seen it applied very recently as a scrubber with the best success. This apparatus, when of suitable capacity, possesses the advantage of eliminating the ammonia with certainty. The liquor can be retained in it until attaining any desired degree of strength. It requires no motive power to keep it in action. It is not liable to be choked and rendered ineffective by the passing tar. It demands no pressure to render it effective, and we believe it is more economical in construction than any other apparatus in use, and for small works we consider it very desirable.

For the economical construction of these and other similar apparatus, we would recommend large slabs of slate, which can be had of all sizes and thicknesses at a cost of one-third of cast-iron.

The gas in passing the condenser, as remarked, is acted on mechanically by its various particles coming in contact with the surface of the pipes, and by this friction a large portion of the tar is deposited. The same effect will be observed when the exhauster is used, as the friction assists in the deposit of the tar.

But gas may be condensed to an excess. When this occurs a portion of its richest qualities is absorbed, naphthaline is deposited in the mains and services, causing continual annoyance, which is particularly the case in winter, when the condensation should be limited.

In hot climates, on the contrary, it will be necessary, as observed, in order to reduce the temperature of the gas to the proper degree, to allow small streams of water to trickle over the surface of the pipes of the air-condenser; as only by these means can the temperature of the gas be reduced in daytime, in localities where the sun shining on the apparatus approaches in warmth that of the gas, as it issues from the hydraulic main.

THE SCRUBBER AND WASHER.

Both these apparatus are employed for one purpose, that is, for eliminating the ammonia from the gas; and their efficacy does not depend solely in removing that compound, but also in rendering it a commercial commodity for sale to manufacturers; or, what is still more profitable, to manufacture the ammonia on the works where it is produced, for which detailed instructions are hereafter given.

The ammonia evolved in the process of carbonization of the coal, is partly obtained in combination with the water produced in the operation, intermixed with the tar from which it is afterwards separated by the difference of their gravities; a portion is deposited in the condenser and other apparatus on the works; another portion is absorbed from the gas by the mechanical action of the scrubber, or washer, and as thus obtained is usually termed ammoniacal liquor. The ammonia is also deposited by the chemical action of sawdust or other fibrous material, being impregnated or intermixed with an acid, or a salt, such as sulphuric acid and the sulphate of iron, both of which are sometimes used as purifying agents. But for the present we will confine our observations to the method of eliminating the impurity by the action of water, which is almost universally employed for the purpose.

Water at ordinary temperatures possesses the property of absorbing about 700 times its own volume of ammonia gas, and advantage is taken of this property in order to eliminate that impurity from the gas. But in proportion as the water increases in temperature so does its affinity, or power of absorbing that compound diminish, and this affinity totally ceases, on the water attaining a temperature of 180° Fah. Hence the necessity for having all the apparatus, such as condensers and scrubbers, at a moderate degree of temperature; at the same time avoiding any excessive degree of cold, which would cause some of the light hydro-carbon vapours to be deposited, and so diminish the quality of the gas as an illuminating agent.

There are numerous descriptions of washers, or scrubbers, employed for removing the ammonia by the action of water, but the apparatus which eliminates the compound with the minimum quantity of water, without deteriorating the illuminating power of the gas, is the best; as by employing a small quantity of water, the ammonia is obtained in a concentrated state, and the liquor will necessarily require less fuel and labour in its manufacture.

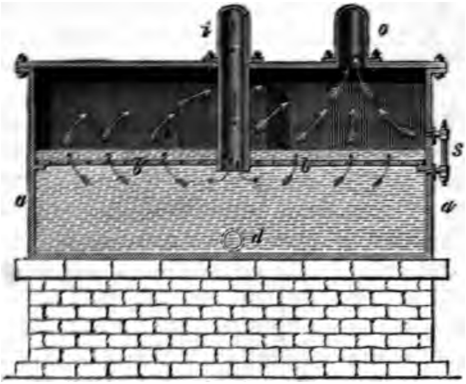


Fig. 26.

Another reason for avoiding any excess of water is, that manufacturers frequently purchase the ammoniacal liquor from the works, when the expenses of transport become a serious subject for consideration. Hence, for the purpose of sale it is essential that it shall be delivered of a certain strength, for, as will be hereafter shown, in all liquor there is but a limited quantity of ammonia in combination with a large quantity of water.

The Washer.

The simplest form of washer is represented in section by the engraving Fig. 26, and consists of a cast-iron cylinder, *a*, closed at the top and bottom, placed on a brick pedestal. The inlet for the gas is indicated by the letter *i*, and the outlet by *o*. The discharge for the liquor is marked at *d*, where a valve is always placed in connection with a seal-pipe, in order to prevent the escape of gas—which is a most important consideration in all the apparatus of a gas-works. A dash-plate, *b b*, generally made of wood and pierced with small holes, is placed about midway in the tank, and when in use the washer is charged with water to a short distance above the dash-plate, the level of which is observed in the glass tube of the water-level gauge *s*. An overflow pipe is usually attached, so that the liquor when augmented in volume by absorbing the ammonia passes to another vessel. A tap is also attached for taking samples of the liquor. When the apparatus is in action, on the gas entering by the pipe *i*, and passing through the holes in the dash-plate, it is subdivided into very small particles, each of which coming in contact with the water parts with its ammonia.

Frequently two or three of these washers are combined and placed at different elevations, in order that the liquor of the highest may by its own gravity flow to the second, and from that to the third, as occasion may require. The foul gas first enters the lowest washer, and passes from there to the second, and hence to the highest, which is supplied with clean water. In some cases a constant stream of clear water enters the highest vessel, and the ammoniacal liquor flows from the lowest, communications being made between the washers for that object.

One important point for consideration in this form of washer is to prevent the water seal becoming too great; a dip of one or two inches is ample, for when this is not regarded, either unnecessary pressure is thrown on to the retorts, or extra work is given to the exhauster and engine.

A washer recently invented by Mr. George Livesey consists of a tank having a number of vertical partitions pierced with small holes, each of which does not exceed a tenth of an inch in diameter. These orifices are sealed by the water, and the gas in its passage through them, is subdivided into minute particles; by these means the liquor acts most effectively in eliminating the ammonia. We have seen these washers in use in several important gas-works, and have heard the most favourable accounts of their efficiency. Moreover, contrary to the opinion of chemists that some of the richest constituents of coal gas are absorbed when brought in immediate contact with water, we have been informed that the illuminating power of the gas is in no ways deteriorated by the apparatus in question.

Already on page 143 reference has been made to a form of condenser which we believe to be well adapted as a washer or scrubber, for the reason that it combines a large surface of water; the liquid gradually flows from one vessel to the other, and can be kept in contact with the gas as long as it may be desired, in order to obtain the necessary degree of strength.

The Scrubber.

The scrubber is another form of apparatus for extracting the ammonia from the gas, and differs from the washer in one respect, that is, whereas in the washer the gas has to force its way through the water, in the scrubber it is only brought in contact with it when passing over the surfaces of pieces of coke, bricks, boards, wood-shavings, or other materials which possess a large area, and are saturated with water. This system was introduced originally with the view of avoiding the pressure demanded by the washer, as it was constructed in the most primitive manner. However, since the general adoption of the exhauster, these objections no longer exist.

There are various kinds of scrubbers, but the kind most commonly employed consists of a cast-iron tower or tank of a height much exceeding its diameter. This is divided into three or more compartments by cast-iron sieves or grids, each of which support the material employed, as shown in Fig. 27, which represents a scrubber suitable for a small works, half in section and half in elevation.

This is a cast-iron cylindrical vessel, containing three grids, on each of which is placed a quantity of coke sufficient to fill the compartment above. At the bottom is a division intended to receive any particles of coke that may pass through the lowest grid. At this point is the inlet pipe for the gas, as well as the outlet for the water. For supplying the apparatus with water, at the top, are two or more horizontal pipes of perforated gun-barrel, attached to a common centre or axle, which pipes are made to revolve by suitable gear-work, and distribute the water regularly over the whole area of the top surface of the coke in the scrubber.

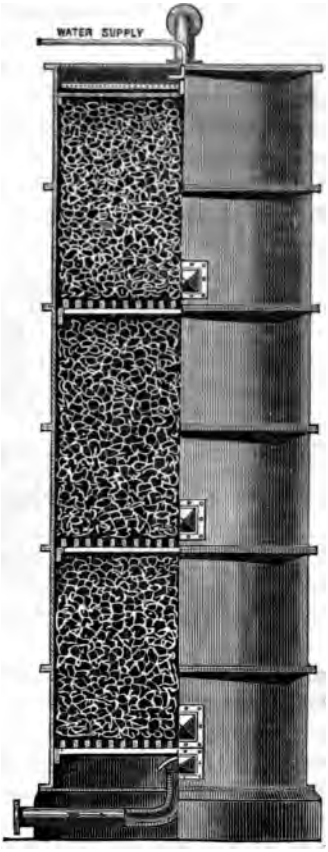


Fig. 27.

Thus the water in its descent, being distributed over the large surface of coke, or other material, absorbs the ammonia from the gas, (and, similar in action to the washer,) in the scrubber the gas first meets with the foulest liquor, and in ascending, it at last comes in contact with the clean water, which removes the last trace of the impurity; that is, supposing the apparatus to be constructed according to the requirements of the works where it is employed. For large works these vessels are made of great magnitude, in some instances of sixty feet high and eighteen feet diameter, which will eliminate the ammonia from one million feet of gas per diem.

The capacity usually allowed for scrubbers is 15 cubic feet per 1,000 feet of gas produced per diem, the height of the vessel being at least three times its diameter. Sometimes the water is distributed by a self-acting apparatus, similar to Barker's mill, or jets are admitted at various points. However, with all the care that can possibly be bestowed on the condensation, and the best arrangements for supplying the water, it happens that the coke or other material in the course of time becomes clogged, and the passage of the water is limited to narrow streams, when this kind of scrubber diminishes in effect, until the coke or other material it contains is replaced.

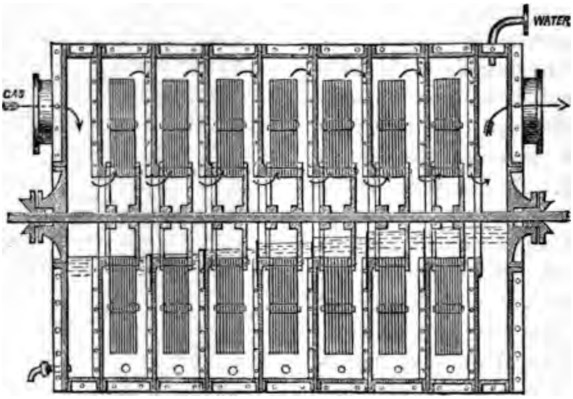


Fig. 28.

Another kind of scrubber patented by Messrs. Kirkham, *Hulett, and Chandler* is represented in longitudinal section in Fig. 28. This consists of a cast-iron case divided into compartments, provided with a revolving shaft which extends the entire length and protrudes at both ends of the case, and is connected to suitable gearing, and driven by motive power.

To this shaft are affixed several series of metal discs, as shown, of somewhat less diameter than the case. Each series is composed of a number of discs which rotate in their respective compartments in such a manner that the water and gas of each compartment is separated from the others.

The action of the apparatus is as follows:—The supply of water, which is at the rate of about ten gallons per ton of coal carbonized, enters by the pipe shown, and is maintained at different levels, so that it flows successively from one compartment to the next, throughout the apparatus, and in the compartment through which the gas passes last, there is always clean water; thus the gas must necessarily be free from ammonia as it leaves the apparatus.

The gas enters at the opposite end to the water and passes as indicated by the arrows through all the compartments in succession, and being brought into contact with the wetted surfaces of the discs, the ammonia is absorbed by the water as the discs revolve. The foul gas, on entering the first compartment, meets with the strongest liquor, by which a large quantity of carbonic acid and sulphuretted hydrogen is taken up.

The advantages of this apparatus are, that unlike the "tower" scrubber, it always has the same amount of wetted surface exposed to the action of the gas, and consequently it cannot fail to be effective. The liquor may be obtained of any desired strength by simply controlling the water supply. The power to drive it is but small, while the space occupied by the machine is very limited.

As already remarked, the presence of a trace of ammonia in gas is not, however, objectionable, and, as we will show, ammonia should not be regarded as an impurity only, but as a *source of profit* to a company. It should, however, be observed that in the event of the scrubbers not being of sufficient magnitude to obtain the liquor of the desired strength, it is pumped several times through the apparatus until that is acquired; and very recently we heard that it was delivered from a works to the manufacturer of 20 ounce strength, when of course the liquor realised a corresponding high price.

At some works, in order to obtain the ammonia, the purifier is charged with sawdust in a dry state, but which has previously been saturated with sulphuric acid; by these means the ammonia is absorbed, and in some localities, situated a considerable distance from the manufacturer of ammonia, this system may be advantageously carried out.

Wherever there is no exhauster the scrubber should be employed, as this avoids the pressure given by the washer.

PURIFICATION BY WET LIME.

The ammonia being removed from the gas, it then becomes necessary to deprive it of the other compounds, and for this purpose the most primitive and best system, so far as regards the purification of the gas, is that known as the wet-lime process.

In this process, the lime, after being slaked, is mixed with water in the proportion of about 48 gallons of the latter to two bushels of slaked lime. It is necessary to mix the lime and water together in a separate vessel, because the prepared lime must be introduced to the purifier in a fluid state. The mixing is commonly effected in a large brick, or iron tank, placed at a higher level than the purifiers. In the centre of the tank is fixed an iron shaft, carrying at its lower end a stirrer or agitator, which is caused to revolve by manual labour or steam, or gas power. By means of this stirrer the lime and water are kept in a state of agitation, the former being mechanically suspended in the latter, in which state it is allowed to flow into one of the purifiers, provided with suitable agitators to keep it in a state of solution, otherwise the lime would be speedily deposited; as when in a state of repose the water does not combine with or dissolve it.

In large works often two or three sets of purifiers are used, each set consisting of three purifiers. When economy of space is an object they are sometimes placed one above the other, at other times side by side. They should always, however, be at different levels, as in working them, it is usual to cause the contents of the highest purifier to flow into the second, and from that to the third, from whence the foul lime is withdrawn. The fresh lime is always admitted into the upper purifier. The crude gas enters the lowest vessel which contains the foulest lime, where it becomes partially purified; it then passes to the second, and from thence to the third, where the process is completed. The revolution of the stirrer of the purifiers is effected by a steam-engine, or a gas-engine. For this object a bevelled wheel on the upright shaft gears into a similar wheel on a horizontal shaft which is driven by the engine.

The wet-lime purifier consists of a cast-iron cylinder entirely closed at the top and bottom, except where the inlet and outlet pipes join it, and the opening required for charging fresh lime-water and drawing off the foul charge. To the inside of the cover of this outer cylinder is bolted an inlet cylinder usually made of cast iron. This inlet cylinder is open at the lower part, and reaches to within a few inches from the bottom of the outer cylinder, but has bolted to its lower flange a wide ring or dash-plate of sheet iron; thus an annular chamber is formed by the inner and outer cylinders. These particulars, however, will be more fully understood from the woodcut, to which reference is now made.

The apparatus, as represented, consists of the annular chamber A A, which is in communication with the outlet K, and the cylindrical chamber B B, into which the inlet pipe C admits the gas from the washer, or scrubber. A dash-plate is attached to the bottom of the inner cylinder, and an angle-iron, *e*, is fixed by bolts to the tank in such a manner as to allow only an inch of space to intervene between it and the iron dash-plate. The bottom of the angle-iron is on a level with the dash-plate, thus the gas has to force its way through the small space between them in order to issue from the outlet. The revolving arms or stirrer *f f* is keyed on to the upright shaft *b*, which works in a bearing fixed on the bottom of the purifier, and passes through a stuffing-box in the lid, and is driven by a bevel-wheel, as already described for the mixing vessel. To the revolving arms *f f* are attached two pieces of bent wrought iron, *h h*, which continue up through the small opening already mentioned, and lap over the dash-plate till they nearly touch the inlet cylinder. The object of this is to prevent the lime from settling; it also keeps the opening clear and free for the gas to pass. The outlet pipe for the purified gas after it has passed through the solution of lime is shown at K. An exterior chamber L is connected with the purifier by a siphon-pipe N; the pipe M is provided

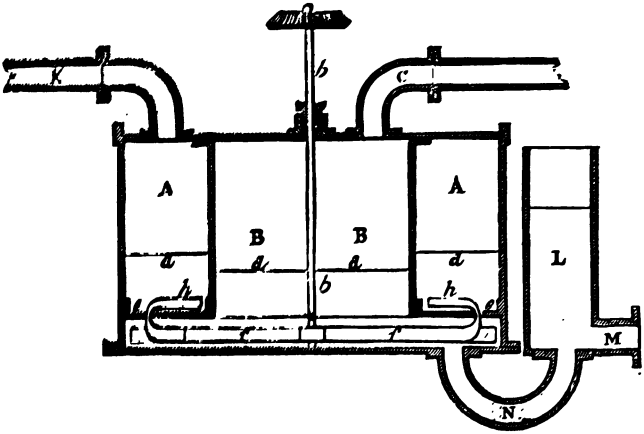


Fig. 20.

with a valve which is not shown, and is for the purpose of discharging the foul lime. The lime and water is conveyed into the purifier through the chamber L, and when it is required to empty the vessel, a valve at M is opened. As the siphon-pipe N must always remain filled with fluid, it is evident that no gas can escape when the lime and water are drawn off. This arrangement is necessary, as when wet-lime purifiers were first used, a serious explosion occurred from the escape of gas along with the spent material. The action is as follows.

The vessels are charged with the cream of lime to the height indicated by the letters *d d*, when the gas, on entering the cylinder B by its pressure, forces its way through the fluid lime, and the gas is deprived of its impurities, in a manner more or less complete, according to the number and size of purifiers adopted.

Wet-lime purifiers are most effectively and economically worked when in sets of three as indicated, all their shafts being driven by one engine. Thus when the third purifier ceases to be effective the lime is withdrawn from it, which is replaced by that of the second, and the first purifier after supplying the second receives a charge of fresh lime.

The general impression is that wet-lime purification is the most perfect mode for the effectual removal of carbonic acid, and the other impurities. But the operation of discharging the apparatus, together with the residues of the process, are so very offensive to the surrounding vicinity, as to prevent this means of purifying being applied except in instances where the works are quite isolated; and even then the difficulty arises how to dispose of the foul lime, or "blue billy," as it is technically termed, the stench from which is so intolerable as to prevent it being deposited with ordinary rubbish, and no practical method has been adopted of applying it, except as luting for the retort doors. Therefore wet-lime purification is seldom adopted at works established in or near towns or cities.

Dry-lime Purification.

In proportion as the use of gas-lighting extended, so were the inconveniences experienced by the refuse of the wet-lime process augmented, until the odour emanating from the blue billy became so intolerant that other means of purifying gas were suggested.

The dry-lime process of purification was invented many years before it was generally practically applied, and a reason for this delay in adopting it, may have been that this system is considerably more costly than the other. However, as by its use a great portion of the nuisance arising from a gas-works situated in confined neighbourhoods were removed, expense was not regarded; therefore to abate the evil, dry lime was adopted.

When quick lime is slakened, reduced into powder, and moistened with water, it is called by chemists the hydrate of lime, and is the material used for absorbing the impurities sulphuretted hydrogen, carbonic acid, and, under some conditions, other sulphur compounds from the crude gas. This is inappropriately termed the "dry-lime process," a name which is very likely to deceive many and occasion much trouble, inasmuch as dry hydrate of lime has little or no power of purification, and only when it is well moistened, is it really effective.

Speaking on this point Mr. Lewis Thompson observes that the peculiar value of the wet-lime purifier depends as much upon the water as on the lime, which statement is corroborated by the superiority of the wet, over the dry lime mode of purification. From this we gather that the greater the quantity of water, the more efficient becomes the lime, but against this advantage, care should be taken to prevent the lime being saturated to that degree, as to obstruct the passage of the gas.

The principal benefits derived from the so-called dry-lime process are, that the heavy pressure on the retorts, which always exists when wet-lime purifiers are used, arising from the causes already stated, is avoided. The residue of dry-lime purification is under certain conditions readily disposed of, being valuable in many cases for agricultural purposes. It is also useful for numerous other objects, but the returns from this source are never important. In dry-lime purification no motive power is required, and the odour arising from the residue is less obnoxious than that from wet-lime purification. These are advantages which have caused this process generally to supersede the other.

Dry-lime purifiers are generally rectangular cast-iron vessels, varying from 3 feet to 30 feet square, and from 3 feet to 5 feet deep. Sometimes in very small works they are made circular; this, however, is only done for convenience or economy in construction. Each purifier contains a series of perforated shelves, or trays, or sieves, supported by suitable bearers of wrought or cast iron, the ends of which are attached to "snugs" cast on the purifier. In large purifiers there are also pillars placed at intermediate distances, to carry the weight of the sieves and purifying material. On these sieves is placed the hydrate of lime, to a thickness of about three or four inches, through which the gas passes; and by the absorptive action of the lime the gas is deprived of its impurities to a degree more or less complete, depending on the various conditions of the magnitude of the purifiers and the efficiency of the lime.

The upper part of the purifier is surrounded by a water lute or reservoir, making a water-tight joint for the cover, of from 9 inches to 24 inches deep, and from 3 inches to 6 inches wide, which is often cast with the purifier and forms part of it, or is attached thereto by bolts and cement. The cover of the purifier is of boiler plate or cast-iron, the latter being preferable on account of its durability; but the increased weight is an impediment to its adoption. The rim or border of the cover is rather deeper than the cistern into which it is placed, and is effectually sealed by the water, thus preventing the gas escaping from that point.

Often the purifier is divided into two compartments, so that the gas ascends through a set of sieves on the one side and descends through another set on the other side, answering the purpose of two vessels. In all establishments, however small they may be, two distinct purifiers at least are necessary to enable the impure lime to be removed from the one, whilst the gas is being purified by the other.

A most important point is to have the purifiers of every denomination of ample magnitude, for although this may increase their cost in some degree, yet it is amply counterbalanced by the saving of labour and economy in the purifying material; which is more particularly the case with dry-lime purifiers, where the lime is a purifying agent, long after it is saturated with impurity, in the ordinary sense of the term.

The number of purifiers in a work is variable; in the majority of establishments a set of four is very usual, their dimensions being determined by the capacity of the works. In addition to these there is often an extra apparatus called the "catch purifier" charged with the hydrate of lime, which intercepts any accidental impurity that may exist in the gas. The general calculation when dry lime alone is used, is to allow one superficial yard of sieve in active service for each thousand feet of gas produced per diem. Thus, a works producing fifty millions per annum, or a maximum of 220,000 per day, will require four purifiers, each having six sieves of about 10 feet square. With large purifiers the gas is in a comparative state of repose, and gives up its impurities more readily than when in rapid motion.

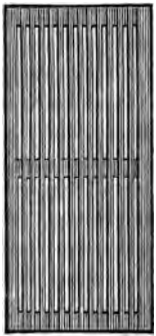


Fig. 30.

The grids or sieves of purifiers were formerly made of wrought and cast iron, but they were liable to numerous inconveniences, such as breakage, from their excessive weight, and in some cases they were speedily obstructed. The grids of the present day are invariably made of wood, as represented in the annexed figure. They are usually of about 2 feet 3 inches long and 18 inches wide, and cost about 8d. or 10d. per superficial foot, and are very durable.

The means of changing the passage of the gas to and from the various purifiers, and shutting it off from those vessels, is sometimes accomplished by a series of slide-valves attached to the pipes, which is costly and attended with inconvenience. A simple means of replacing these valves was supplied by the late John Malam, whose name is intimately identified with the progress of gas-lighting, and more particularly in connection with the gas-meter. To that gentleman we are indebted for the beautiful modification of the hydraulic valve, by which the gas is received at its first entry into the purifier, made to traverse all the various vessels and pipes in succession, and is discharged from them in a pure state, to be stored up in the holder.

The hydraulic valve consists of a cast-iron tank, the diameter and height of which depends on the number and size of pipes connected with the purifiers.

Fig. 31 represents a plan of a set of purifiers with their corresponding hydraulic valve. A B C D are the four purifiers, but for want of space only part of C and D are shown. The purifiers A and C are enclosed by the covers; those indicated B and D are open, showing the mode of construction and part of the wooden grids placed ready for receiving the lime. At the central hydraulic valve marked E, meet the various pipes conveying the gas to and from the purifiers, also the inlet pipe *a* and outlet *o*. The pipes marked 1, 3, 5, and 7 are the inlets, which convey the gas from the central valve to the respective purifiers; the pipes marked 2, 4, 6, and 8 convey the gas from the purifiers to the valve.

For a set of four purifiers, each being 12 feet square, with 12-inch connection pipes, the tank is about 4 feet 6 inches in diameter, and 3 feet 6 inches deep. In the bottom there are nine holes perforated to permit the pipes

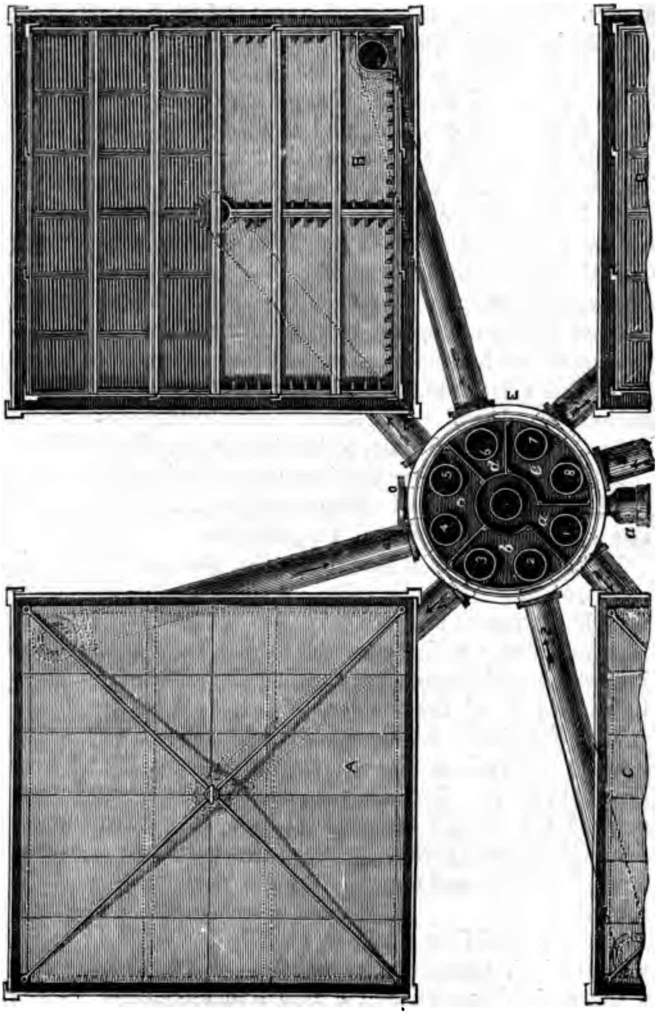


Fig. 31.

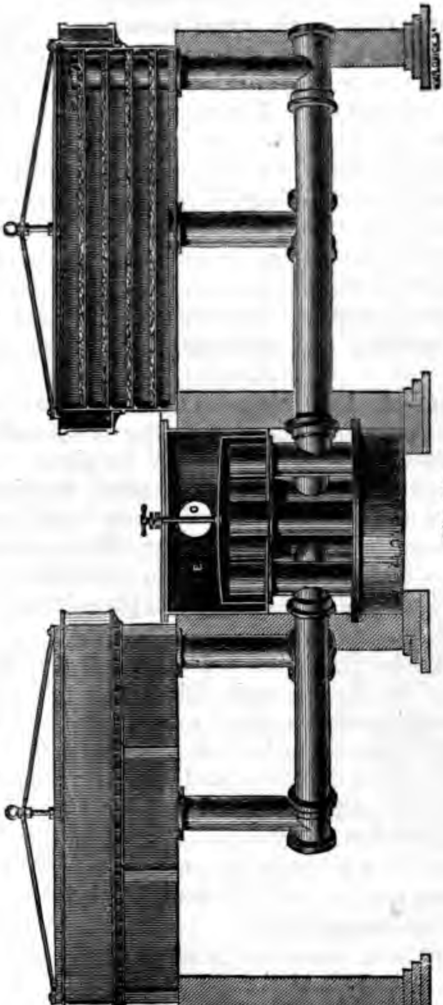


Fig. 32.

to pass freely, and these pipes are attached to the tank by flanges and bolts in the usual manner. The tank has a cover, through which passes a rod working in a stuffing-box, for the purpose of lifting the vessel which regulates the direction of the gas. The covers of purifiers are strongly stayed, and are lifted by means of a screw or crane.

Fig. 32 represents two of the purifiers described, the one in elevation, the other with the front plate removed to show the interior and a section of the hydraulic valve. There are four sieves for the lime, through which the gas traverses, and when above the top layer descends the outlet pipe, returns to the central valve, from thence to another purifier, and so on throughout the number in use.

The vertical pipes in the tank of the valve E are about 18 inches long; and, when in operation, the tank is filled with water to the level of the top of the pipes. Under the central valve is a tank, in which stand the pipes, which are open at the bottom; but as the tank is filled with water the gas is prevented from escaping. This system has the advantage that no syphons are required to be attended to, and any condensation that may take place in the pipe flows into the tank.

To complete the central valve there is a gas-holder or bell closed at the top, and divided to within 4 inches of the bottom into five vertical compartments. This vessel encloses the nine pipes in such a manner, that the inlet and outlet pipes of two separate purifiers are respectively isolated in the compartments *b* and *c*, whilst the inlet and outlet of another purifier are isolated in the division *e*. That marked *a* connects the central pipe with the inlet of the first purifier, and the compartment *d* contains the outlet of the last purifier.

We will now trace the progress of the gas from its entrance to its exit to the gas-holder. The tank having been supplied with water, the gas flows by the centre pipe under the bell into the compartment *a*. From there it enters the pipe 1, which leads to the purifier C, and after ascending through the layers of lime it passes down pipe 2 to the cylindrical vessel into the compartment *b*. Here also it can only escape by the pipe 3, and through the lime of purifier A in the direction of the arrows back to compartment *c*, from thence into purifier B, and after traversing the layers of lime again returns to compartment *d*, where there is an opening in the top of the cylinder, through which the gas escapes to the holder by the orifice *o*, on the side of tank. The compartment *e* contains the inlet and outlet of the purifier D, so that the gas cannot enter therein, and this being out of action, affords the facility of changing the lime.

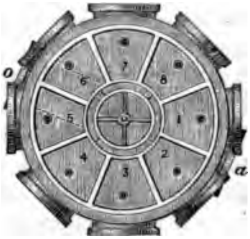


Fig. 83.

It will be observed that by these means only three purifiers are in operation, the fourth in the meantime having the foul lime removed and fresh supplied. In order to change the passage of the gas, the cylinder is then raised by the handle of the rod (which passes through the stuffing-box) until the partitions clear the pipes. It is then turned a fourth of a circle and allowed to descend into its seat, when the gas first enters the purifier A, from there to B and D, whilst purifier C is thrown out of action for the purpose of changing the lime. By these simple and ingenious means the passage of the gas to and from the purifiers is regulated with the greatest facility.

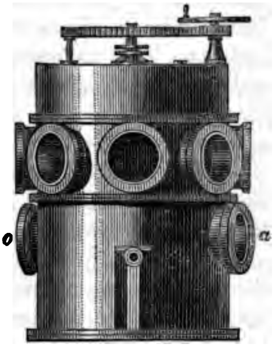


Fig. 84.

Within the last few years the hydraulic valve has been superseded by the rotary slide-valve, in which the whole arrangement is the same as in the former, as shown by the annexed Fig. 33, which represents the plan of the seat of the valve, with the divisions indicated, and corresponding connections.

Fig. 34 represents an elevation of the valve, the cover of which is actuated by a pinion working into the rack, but sometimes the cover is affixed to a rod, which passes through a stuffing-box on the top of the cylinder, forming the upper part of the valve, and is actuated by a handle.

On the tops of the purifier covers there should always be valves, or stop-cocks, of large dimensions, so as to admit air into the purifier when in the act of raising the covers, or to expel it when lowering them. Also very small taps with a single jet attached, intended for trying the purity of the gas by means of tests. When the gas is changed from one set of purifiers to the other, the cover of that purifier requiring fresh lime is removed, when the waste lime is discharged, wheeled away, and fresh lime substituted. A very common impression exists that the lime to be effective should be carefully sifted and reduced to a fine powder. This is erroneous; all that is requisite is to well slaken it; which effected, it should always be moistened to that degree that when pressed in the hand it adheres together in a mass like snow; but if too much wetted it is likely to obstruct the passage of the gas, and should be avoided. A layer of about three or four inches thick on the sieves is the most effective.

It is generally accepted as a rule that a bushel of quick lime, which, when slaked and rendered into hydrate, increases to about 2½ times its original volume, is sufficient by the process in question to purify the gas derived from a ton of coal. This, however, must greatly depend on the quality of the lime, for there are some descriptions which contain a large percentage of argil, and although admirably adapted for hydraulic mortar, they are ill suited for the purification of gas.

Another consideration is, that some coals contain considerably more sulphur compounds than others, therefore no general rule can be defined; but when properly treated, and the lime of average quality, the quantity stated may be accepted as a good approximation of that required for the purification of gas.

In the ordinary method of purifying, the foul gas is admitted first into the purifier the most impregnated with impurity, thence it passes to the second, and so to the third, where the lime is comparatively clean. When purifiers are of ample magnitude, the foul lime if properly moistened, remains an active agent in the purification to the last; therefore it is only when the gas begins to indicate signs of impurity at the fifth division, supposing six divisions of purifiers to exist, that they should be changed, and by the employment of apparatus of ample capacity only, can lime be employed to the best advantage.

Oxide of Iron Purification.

In 1849, the discovery was made that certain oxides of iron possess the property of absorbing the sulphuretted hydrogen from the gas, and that by this process the nuisance which attended the other systems of purification were avoided. Moreover, that the foul material after being exposed a certain time to the atmosphere, was again revived and capable of repeating its purifying action. Thus in ordinary operations with the oxide of iron the same material may be employed for thirty or forty times; always being effective but becoming less forcible, according to the number of times it is brought into action.

There are different descriptions of oxides, but those most extensively used are the natural in combination with earthy and fibrous material, which are sold at various prices corresponding, we may assume, with their respective qualities. Others again, as those to be had of drysalters, are intermixed with sawdust, and in the selection of these, the manager should be guided by the experience of others, as it is somewhat difficult to arrive at a fair conclusion on the value of this material, unless by experiment or the advice of a disinterested party.

Some firms arrange to supply fresh oxide gratuitously to large establishments, on the condition of having the privilege to cart away the foul material. Other gas companies have an arrangement for the supply of oxide, either by weight, or measure, or by the quantity of gas purified, or the quantity of coal carbonized; however, in this, as in other matters, efficiency of operation should be the first, and price the secondary consideration. The quantity of sulphur absorbed by the several descriptions of oxides is variable; some of those usually employed will retain about 35 per cent. of their weight, and on being gently roasted the sulphur is expelled, when the oxide becomes again a purifying agent, but of less activity than before. According to a circular of a chemical company, established principally for the supply of fresh, and manufacture of foul oxide, their material absorbs twice its weight in sulphur.

The writer has employed the material commercially known as oxide of iron, intermixed with sawdust, which answered every expectation on the grounds of efficiency, economy, and freedom from nuisance: but all oxides of iron are not effective for the purification of gas; therefore, although this material may in some instances be employed with advantage, it cannot always be relied on. Before purchasing, samples of the oxide should be obtained, and its power for absorbing sulphuretted hydrogen ascertained, for which instructions are hereafter given.

In using the oxide of iron of commerce, or others containing a large quantity of close solid matter for purification, they are generally intermixed with sawdust, slightly moistened, and placed in the dry-lime purifiers in layers similar to the lime, but in greater thickness, and when the oxide ceases to absorb the impurity, it is withdrawn and placed on a paved floor for the purpose of re-oxidation. There are natural oxides which contain a certain amount of fibrous material, and are employed in the state they are received without sawdust, but in all cases before use they should be properly moistened.

This means of purification removes effectively the sulphuretted hydrogen; and when used little odour arises from it; but for abstracting carbonic acid, lime must be employed.

In this method of purifying, the oxide of iron and the sulphuretted hydrogen are both decomposed, the oxygen of the former uniting with the hydrogen, and the sulphur and iron combining to form sulphuret of iron. When the impure material is withdrawn from the purifiers, and exposed to the atmosphere, it liberates a portion of its sulphur, and absorbs oxygen, to form again the oxide of iron; the other portion of the sulphur, being precipitated, combining with the iron. At each revivification the deposit of sulphur is increased, and when the sulphur forms about 50 per cent. of the mass, usually the oxide is no longer serviceable as a purifying agent.

Oxide is always charged in much thicker layers than lime, generally about 8 or 10 inches, but to what degree must depend on its nature and weight, together with the size of the purifiers. The thicker the layer the better, so long as the pressure is not inconveniently increased. When taken from the purifiers, the spent oxide has a dull black purple, and with some kinds a dirty green, appearance, and is then laid a thickness of 10 or 12 inches on the ground at a point especially arranged for the purpose of revivification. The foul oxide is occasionally turned over and broken up from day to day, in order to expose all its particles to the action of the atmosphere, and when it resumes its original colour, it is suitable to be again employed. Considerable labour is incurred in this, which is amply compensated by the slight expense of the purifying material. Fresh oxide has a tendency to ignite when first used and withdrawn from the purifier; for this reason only a portion of new material should be intermixed with the old, as occasion may require.

As it is desirable to know the capacity of any particular sample for absorbing sulphuretted hydrogen, as well as to ascertain the quantity of sulphur in the spent oxide, the methods of ascertaining these points are here given from Richards' "Treatise."

TO ASCERTAIN THE VALUE OF ANY PARTICULAR OXIDE AS A PURIFYING AGENT FOR ABSORBING SULPHURETTED HYDROGEN.

There is but one way in which the value of oxide of iron for the absorption of sulphuretted hydrogen can be estimated, and it is equally applicable to lime and all other purifying agents, which is as follows, and requires the use of two bent tubes, as represented in the annexed diagram, Fig. 35, with other apparatus, as weights, scales, &c.

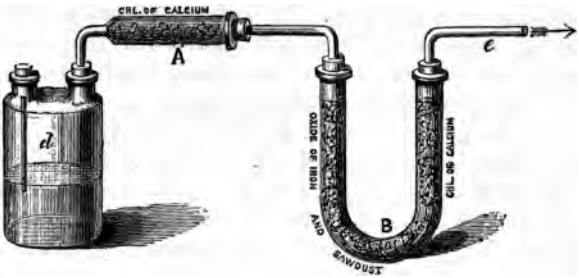


Fig. 35.

The tube A is charged with pieces of chloride of calcium, and adjusted with corks so as to fit into a Wolff's bottle, *d*, as shown, also to receive the end of a bent pipe that is fixed into a large U-shaped tube B. This U tube should have one of its legs and the bent part of it filled with 200 grains of the oxide in question, which has been previously well mixed with an equal weight of sawdust; the other leg to have a small piece of cotton wool put into it, and upon this sufficient chloride of calcium to fill the leg, which is then to be closed with a cork, through which a small pipe passes, as shown in diagram.

The tube B, when charged, is to be carefully counterpoised in a balance before it is fixed to the tube A; after which acid is to be poured very gently into the Wolff's bottle, upon sulphuret of iron, or any other sulphuret that will cause a gradual production of sulphuretted hydrogen, which is to be continued until that compound passes freely out of the small tube *e*, fixed to the tube B. After this evolution of sulphuretted hydrogen has continued for about ten minutes, remove the tube B and weigh it with its contents, in order to ascertain how much sulphuretted hydrogen has been absorbed. By these means the weight of the sulphuretted hydrogen absorbed will be ascertained, which gives the value of the oxide as a gas-purifying agent.

The use of oxide of iron is an economical method of purifying gas, but as stated, it is only available so far as regards sulphuretted hydrogen, as it possesses no action whatever on the other impurities. The spent oxide is sometimes purchased by manufacturers for extracting the sulphur, when it is generally required that it shall contain 50 per cent. of that material. Therefore, when deciding on any particular oxide, when the foul material is intended for sale, it should be capable of absorbing the percentage of sulphur stated.

To ascertain the quantity of free sulphur in spent oxide: this is acquired by dissolving the sulphur in combination with the oxide, with bi-sulphide of carbon and then evaporating the liquid, when the crystals give the weight of the sulphur contained in the oxide.

Within the last few years a system of reviving the oxide of the purifiers without removing the cover or displacing the material, has been adopted. For this purpose a slight alteration in the purifier is required, by the addition of an extra inlet and outlet, connected with their corresponding valves. A Körting's blower, similar to the steam exhauster already mentioned, is then attached to the extra inlet, and connected to a steam pipe provided with a regulating tap. The extra outlet being open, air is conveyed through the purifier and the noxious vapours pass by the outlet. The purifying material may be revived twice or three times by these means; but on account of the oxide caking, thus becoming too compact in its nature, and obstructing the passage of the gas, the process cannot be continued beyond the number of times stated.

During the process of revivification the oxide becomes heated in consequence of the chemical change in its nature, and, on the action ceasing, it returns to its normal temperature. In using the apparatus and employing new material, a proportionately small quantity of air is admitted, when the steam in combination therewith prevents the oxide overheating.

SULPHATE OF IRON AND LIME PURIFICATION.

Another method of purifying gas is by means of the sulphate of iron and lime. The mode of preparing this mixture is as follows: take any given quantity of sulphate of iron (green copperas), mix with it half its weight of recently slaked lime, and adding sufficient water to make the whole damp; then grind it into pulp in a mortar mill, and spread the green coloured pulp on the ground in a dry place, and leave it so for twenty-four hours, when it will have become dry and of a red-yellow colour, in which state it is broken into a coarse powder, and is then fit for use in precisely the same way as lime is used; that is, it is spread on the grids of the purifiers a thickness of about three inches, when, supposing the purifiers of ample capacity, it will remove from the gas all the ammonia, all the sulphuretted hydrogen and part of the carbonic acid.

THE SULPHUR COMPOUNDS.

We now come to one of the greatest difficulties experienced during many years in gas purification, that is, the method of eliminating the sulphur in "other forms" than sulphuretted hydrogen, which expression has been introduced on account of the obscurity that existed concerning those compounds.

It may be observed that when gas containing an excess of the sulphur compounds is burned in close rooms the effects are exceedingly disagreeable, and it was highly desirable that gas should be purified to such an extent as remove these entirely. This, however, has been found impracticable, consequently the Legislature has decreed in the various Acts of Parliament that gas should be of that degree of purity that not more than 20 or 25 grains of sulphur in any form should exist in 100 cubic feet of gas. In practice, however, this degree of excellence was for some time difficult of being obtained, when chemists and engineers alike exerted themselves without avail. Very opportunely Mr. R. H. Patterson, then one of the Metropolitan Gas Referees, directed his attention to the subject, when he discovered that if the gas were in the first instance freed from carbonic acid, the sulphur "in other forms" was readily absorbed by the sulphide of calcium, or the ordinary foul lime purifiers; and by this process, the quantity of sulphur per 100 feet of gas is very considerably less than required by Parliament.

The means formerly adopted for testing the presence of sulphur in gas was with the apparatus Fig. 36, and in the manner to be described, which for all the practical purposes is sufficiently accurate. The apparatus consists of a jet flame, *a*, of the gas under examination, over which is a chimney gradually contracted into a small tube, *b b*, half an inch in diameter, which tube is bent and carried through a metal cylinder, *c*, about 18 inches long and 2 inches diameter. This cylinder is kept full of cold water, which is retained by means of india-rubber washers and the screwed caps, *g g*, at each end, which make perfect joints, and prevent the water escaping. The funnel *d* is for supplying the tube with water, any excess of which overflows by the syphon *f*. Hence the vapours which escape from the combustion of the gas at *a* pass through the tube *b*, where they are condensed, and drop in the state of fluid into a glass placed at the end to receive them; the carbonic acid escaping at the same open end of the tube. The water which drops from the tube is generally colourless, nearly tasteless, but with a peculiar and not unpleasant odour.

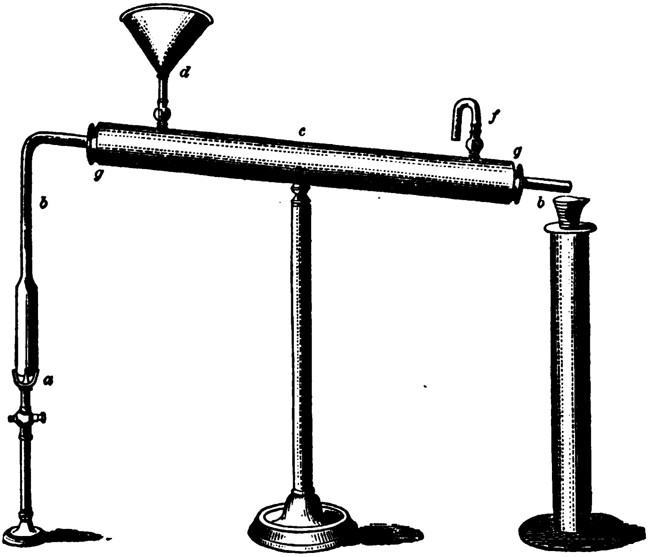


Fig. 36.

When a drop of the nitrate of baryta is added to the water condensed from the combustion of ordinary gas, a flocculent white powder immediately discolours the water, which is the sulphate of baryta.

To obtain the whole of the sulphur present some carbonate of ammonia should be placed around the jets of gas in a vessel for the purpose. The vapour of ammonia in passing up the tube combines with the sulphurous acid, and the sulphur compound is condensed in the water in the form of sulphate of ammonia.

This at one time was considered a very severe test, but modern requirements demand other and more perfect means.

The following is an abstract of the instructions given by the Metropolitan Gas Referees for testing the sulphur compounds other than sulphuretted hydrogen, it being understood that the latter is readily discovered by the ordinary tests:—

"The gas for this test shall be burnt at the rate of about half a cubic foot per hour, until ten feet is consumed, when the supply is stopped by a self-acting movement.

"The apparatus to be employed is represented by Fig. 37, and is of the following description: the gas is burnt in a small Bunsen burner with steatite top, which is mounted on a short cylindrical stand perforated with holes for the admission of air, and having on its upper surface a deep circular channel to receive the wide end of a glass trumpet-tube. On the top of the stand, between the narrow stem of the burner and the surrounding glass trumpet-tube, are to be placed pieces of commercial sesquicarbonate of ammonia weighing in all about two ounces.

"The products both of the combustion of the gas and of the gradual volatilization of the ammonia salt go upwards through the trumpet-tube into a vertical glass cylinder, packed with balls of glass, to break up the current and promote condensation. From the top of the cylinder there proceeds a long glass pipe or chimney, serving to effect some further condensation, as well as to regulate the draught and afford an exit for the uncondensable gases. In the bottom of the cylinder is fixed a small glass tube, through which the liquid formed during the testing, drops into a beaker placed beneath.

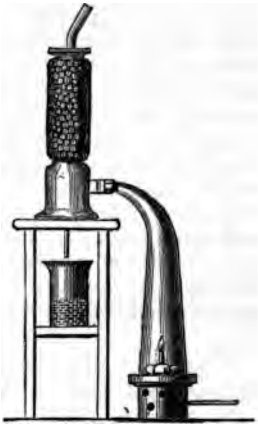


Fig. 37.

"All the connections of the various parts being perfectly tight, the apparatus being properly constructed, and the burner not consuming more than half a cubic foot per hour, the gas examiner shall proceed as follows.

"At the end of each period of testing, the cylinder and trumpet-tube are to be well washed out with distilled water. Fresh pieces of sesquicarbonate of ammonia are to be used each day.

"The liquid in the beaker and the water used in washing out the apparatus to be put into a flask or beaker, covered with a large watch-glass—treated with hydrochloric acid, sufficient in quantity to leave an excess of acid in the solution—and then very gradually raised to the boiling point. An excess of a solution of barium chloride is now to be added, and the liquid again boiled for five minutes. The vessel and its contents are to be allowed to stand till the barium sulphate settles at the bottom of the vessel, after which the clear liquid is to be as far as possible poured off through a paper filter. The remaining liquid and barium sulphate are then to be poured on to the filter, and the latter well washed with hot distilled water. (In order to ascertain whether every trace of barium chloride and ammonium chloride has been removed, a small quantity of the washings from the filter should be placed in a test tube, and a drop of a solution of silver nitrate added; should the liquid instead of remaining perfectly clear become cloudy, the washing must be continued until on repeating the test no cloudiness is produced.) Dry the filter with its contents, and transfer it into a weighed platinum crucible. Heat the crucible over a lamp, increasing the temperature gradually from the point at which the paper begins to char up to bright redness. When no black particles remain, allow the crucible to cool; place it when nearly cold in a desiccator over strong sulphuric acid (to prevent absorption of moisture), and again weigh it. The difference between the first and second weighings of the crucible will give the number of grains of barium sulphate. Multiply this number by 11 and divide by 4: the result is the number of grains of sulphur in 100 cubic feet of gas."

From the preceding we can understand the extreme delicacy observed in the modern method of gas-testing; and although, so far as we are aware, the various details are not adopted by any other gas companies than those under the control of the Board of Trade, it is considered necessary to introduce these instructions in order to illustrate the most advanced operations in connection with our subject.

The tests for ammonia, sulphuretted hydrogen, and carbonic acid, are turmeric paper, acetate of lead paper, blue and red litmus papers, and lime water, for preparing which instructions are here given.

To Prepare Blue Litmus Paper.

In a stoppered bottle put half an ounce of pulverised litmus, and to this add three ounces of cold water, which should be well shaken, and left some time to dissolve. The liquid is then filtered by allowing it to flow through a funnel made of white filtering paper. Then place it in a clean plate, in which dip some pieces of white filtering paper, and when they are well soaked hang them on a line to dry. This effected, the paper is cut into strips of the desired size, generally about two and a half inches long and half an inch wide. These are then either secured together to form little books of two dozen leaves each, or are put in a wide-mouthed bottle well corked, kept in a drawer away from the light; for such is the sensitive nature of these tests that any carbonic acid existing in the atmosphere would change their colour, which is also influenced by the action of light alone.

The blue litmus paper is employed to detect the presence of acids in gas; such as carbonic acid, or sulphuretted hydrogen; but for this object it should be previously slightly moistened.

To Prepare Red Litmus Paper.

Take a quantity of the blue solution of litmus mentioned, and add cautiously, drop by drop, a small quantity of very dilute sulphuric acid, until a piece of filtering or white blotting paper, when dipped therein, acquires a distinctly red tinge when dry. Pieces of white filtering paper are then soaked in the solution, after which they are hung up to dry and cut in slips, as already described. These slips must be kept well protected from both air and light, as the slightest trace of ammonia or other alkali, would change their colour.

To Prepare Turmeric Paper.

Turmeric paper is prepared by pouring three ounces of spirit of wine upon half an ounce of turmeric powder in a clean stoppered bottle; shake it daily, and at the end of four days let it repose, so that the brown powder will settle at the bottom, and leave the liquor above clear. Then place the liquor in a clean plate, into which dip some pieces of white filtering paper, and when they are well soaked hang them on a line to dry. This done, the paper is cut into strips of the dimensions already stated when treating on the blue litmus test, which are then put in a wide-mouthed bottle, well corked and kept in a drawer away from the light. This, like the litmus and acetate of lead tests, should be slightly moistened before being used. Turmeric paper, when exposed to a jet of gas containing ammonia, is changed from its yellow colour to a reddish brown. Ammonia is also detected by dipping a glass rod into hydrochloric acid and holding it in a stream of the gas, when, if ammonia be present, a white cloud of sal-ammoniac will be produced.

To Prepare Acetate of Lead Paper.

In a bottle containing two ounces of distilled water place a quarter of an ounce of crystallized acetate of lead, and when thoroughly dissolved, saturate pieces of white bibulous paper as described, and when dry cut in slips and bottle as already stated. On this test being exposed to gas containing sulphuretted hydrogen, it becomes darkened and eventually brown; if after an exposure of three minutes the paper does not become discoloured, the gas may be considered free from this impurity. When applying either of these tests the paper is slightly damped and held within about a quarter of an inch from a fish-tail burner from which the gas is issuing in full stream.

To Prepare Test for Carbonic Acid.

Into a bottle containing a quart of water put four ounces of quick lime, allow it time to dissolve, shake it occasionally, afterwards let the lime settle, and when perfectly clear, transfer the liquor to another bottle, which should be kept securely corked. For testing, a piece of ¼-inch lead pipe or india-rubber tube may be attached to a small tap, when the gas under examination is allowed to blow through a quantity of the lime water placed in a wine-glass or other suitable vessel. Should the water remain clear after a trial of two minutes the gas may be pronounced free from carbonic acid; but, in the presence of this, the lime water becomes cloudy or milky, according to the quantity of the impurity.

In many gas-works the "constant test" shown in Fig. 43 is employed. For that purpose two pieces of test paper, acetate of lead and turmeric paper, are suspended within the vessel, their ends dipping into two cups containing water, by which means the papers are always kept moistened. A burner, consuming about two feet per hour, is attached, and the gas in its passage to the burner issues from the two jets and impinges on the two slips of paper; the case being of glass, allows the test papers to be observed. When gas is well purified, sometimes these will remain in the apparatus twenty-four hours without becoming soiled.

It may, however, be more convenient for many gas managers to purchase the test papers, together with the apparatus mentioned hereafter, when treating on the manufacture of the sulphate of ammonia such as the Twaddle hydrometers, the alkalimeter, and the test acid. The only firm that supply them that we are aware of is, A. Wright and Co., Westminster.

CHAPTER XI.

GAS-HOLDERS.

The earliest Gas-holders—Gas-holders, how constructed—Gas-holder Tanks — Brick Tanks — Portland Cement—Roman Cement — Puddle, cost of—Specification of—Stone Tanks—Composite Tanks—Cast-iron Tanks—Specification of Compound Tanks—Annular Tanks—Guide-columns and Girders—General Conditions of Contract—The Gas-holder—Single Lift—Telescopic—Mr. Wyatt's Holder—Specifications of Apparatus for Gas-works of Various Dimensions.

As observed in our historical sketch, the gas-holder was invented about 1781, at the period when the existence of gases began to attract the attention of scientific men.

These vessels were originally termed gasometers, which term is sometimes even now applied. This name was given by the inventor of the apparatus, who at first intended it only as a measurer of gas for experimental purposes; but as they are seldom used for measurement, but are mere vessels of capacity or stores, the simple name of gas-holder is more expressive and appropriate.

The gas-holder is composed of two distinct parts, one of which contains water, and is called the tank, the other is the vessel which contains the gas, being really the gas-holder. On the Continent the former is very generally termed the "cistern," and the latter the "bell."

The earliest gas-holders were made in the form of cubes and other rectangular figures; but these possessed several disadvantages, independently of the waste of material required to construct a rectangular figure, as compared with that necessary for a cylindrical vessel of any given capacity. The corners and angles of the square figures were also found to require bracing, and other precautions were requisite in order to render the resistance uniform.

In the earliest years of gas-lighting, wooden tanks were made for the gas-holders to work in, but this was at a time when these vessels did not exceed in size some of the large vats, or backs, in use at the great porter breweries. The construction of these wooden tanks was in fact intrusted to back-makers, who used to guarantee the duration of the vessels for some period of time agreed on; however, these tanks were speedily destroyed by the action of the ammoniacal liquor contained in them corroding their hoops; besides, it is evident that the rapid increase which took place in the consumption of gas, and consequently the size of gas-holders, required the adoption of a different material for the tanks.

After a deputation from the Royal Society, with Sir Joseph Banks at its head, had visited the gas-works of the Chartered Company in Westminster in the year 1814, they strongly recommended Government to restrict the company from constructing gas-holders exceeding 6,000 feet in capacity, which were moreover to be confined in very strong buildings. When Clegg published his work in 1841, he says, "Gas-holders are now constructed to contain 250,000 feet." Since then the dimensions of gas-holders have been increased twelvefold, as there actually exists at the Phœnix Company's station a holder of the capacity of 3,000,000 cubic feet; and in the course of a short time even these colossal dimensions will be surpassed. Indeed, Mr. Wyatt proposes to construct for the Gas-Light and Coke Company, a holder of 5,000,000 feet, to which we refer hereafter, and Mr. Livesey has the tank of a holder of like capacity now in the course of erection.

At the present time, and indeed since 1818, gas-holders have invariably been made cylindrical. The tank is a large cylindrical vessel, usually constructed, for the sake of economy, of brickwork, masonry, or concrete; but when the ground is marshy, or when water exists abundantly a short distance below the surface of the earth, which would prevent the construction in brick or masonry at a moderate price, then tanks are made in cast iron, and, indeed, in small works, they are sometimes of wrought iron. In the interior of the tank there are two vertical pipes for the admission and egress of the gas, called the inlet and outlet pipes, the former being in direct communication with the manufacturing apparatus, the latter with the mains which convey the gas to the town. These pipes rise a few inches above the level of the top of the tank, so that the water cannot overflow into them. A series of columns or standards, generally of cast iron, but frequently of wrought iron, are placed at equal distances around the tank for the purpose of guiding the holder.

The holder is a cylindrical vessel closed at the top, which is termed the roof, and open at the bottom, made of sheet iron, varying in thickness according to the dimensions of the apparatus; the smaller sizes being made of thinner material in order to avoid an excess of pressure; whilst those of very large dimensions are of stout plates for the purpose of obtaining sufficient pressure, or force, to expel the gas to the burners. The holder is somewhat less in diameter, but of the same depth as the tank in which it is placed, and is sometimes suspended by chains which pass over grooved pulleys and counter-balance weights; but more frequently it is only guided by rollers attached around its lower and upper edges, which work against suitable guides in the tank and on the columns, in such a manner, as to permit the holder to ascend and descend in the tank with freedom.

The action of the gas-holder is very simple, and the tank in which the holder is immersed being filled with water, it is then ready for use. There is a space between the surface of the water and the roof of the holder; the gas enters by the inlet pipe into this space, and with the force it acquires in being expelled from the coal, pressing on the surface of the water and underneath the roof, and over the whole area of both, causes the holder to rise. Thus, by its own force or pressure, the gas provides room for itself, and in proportion to the quantity entering, so does the holder rise out of the water. For instance, a holder having 100 feet area, or about 11 feet 4 inches diameter, in rising 10 feet will receive 1,000 cubic feet of gas, and in descending the same quantity will be expelled.

The water in the tank serves three purposes; it is the means of resistance for the gas to lift the holder, it prevents the gas escaping or intermixing with the atmosphere, and is the means of expelling the gas when the holder descends.

Gas-holders, although often suspended, are never entirely counterbalanced, but always have sufficient weight to give the necessary pressure to force the gas through the mains and burners. A gas-holder when in action should never be filled entirely, but at least one plate, and in telescopic holders, the two lowest plates, should be left immersed in the water, in order to allow for any expansion of the gas; and in our opinion a large portion of the "unaccounted for gas" is lost, at the gas-holder, by overfilling, when any increase of temperature expands the gas, and causes the holder "to blow."

In the department of gas engineering there are several manufacturing firms of eminence, who devote themselves to the manufacture of gas-holders, and the concentrated attention which the subject thus receives has undoubtedly led to very favourable results. An engineer in erecting a works may receive tenders for his gas-holders from a number of well-qualified contractors, who have relatively their own method of construction, and thus he may be saved all the trouble and responsibility of designing these vessels himself.

As explained hereafter, there are the single, the double, and the treble lift holder. By means of the two last the capacity of a holder for a tank of any given dimensions may be nearly doubled by the double lift, and trebled by the three-lift holder.

Gas-holder Tanks.

The tanks of gas-holders are formed either of brickwork, masonry, cast iron, and sometimes, although very rarely, of wrought iron, as well as a compound of materials; and within the last few years they have been built of concrete; to each of which constructions we will now refer.

Brick Tanks.

When the nature of the ground is solid and permits of the tank of a gas-holder being constructed in brickwork or masonry, the tank is sunk to a considerable depth, and, as generally built, the top is about 1 foot 6 inches or 2 feet above the level of the ground, for the purpose of preventing anything from falling accidentally into it; but in some cases, where water prevents the excavation being carried sufficiently deep, tanks of brick or masonry are made to project as much as 6 feet above the level of the surface. When this occurs they must be remarkably well constructed and of increased thickness; also, for greater security, the part projecting above the ground should be bound with one or more iron hoops, similar to those employed in cast-iron tanks.

Formerly the whole of the ground in the centre of the tank was removed, making the bottom level; this system, however, is now superseded by leaving a mound in the centre, in the form of the frustum of a cone or a part of a sphere.

Whatever may be the kind of tank intended to be erected, the first consideration is the foundation, and the nature of the ground where it is to be constructed. The choice will also depend on the description of material at hand and the price; thus whether bricks, stone, or ballast, are the most available, will decide on the description of tank to be erected. But should the site be doubtful as to its stability or subject to any inundations, or should the required skilled labour or material for a brick or stone tank not be at command, a cast-iron tank will be the most suitable; and although it may be more costly, it is much safer than any other, particularly when the proper men for building are not available.

Within the last few years, by the more general application of Portland cement, a remarkable change has taken place in the construction of the class of tanks under consideration; and in many cases where clay suitable for puddle cannot be obtained at a reasonable cost, brick tanks are built without it; which with good material and suitable workmen at hand offers no serious difficulty, but demands great care.

When building a brick tank without puddle the bricks should be well burnt, and thoroughly saturated with water just before being laid; and each brick should be well embedded in the hydraulic mortar or cement, so that the whole of the work shall be solid. Beyond these precautions there is nothing particular in the construction of a holder tank, more than in any other kind of building.

However, it is generally considered by engineers, that when puddle can be procured at a moderate cost, the whole surface of flooring of the intended tank, should have a layer of about 12 inches of that material, well tempered and trampled down before commencing the building; and of course this, as well as the puddle at the back of walls, will have to be considered in the dimensions of the excavation. This opinion we have no hesitation in saying is old-fashioned, and with the excellent building materials such as blue lias lime, and Portland cement at our disposal, the use of puddle can be entirely discarded.

The thickness of brickwork or masonry for a tank, must depend entirely on its size and depth. Small tanks—on account of not having the same column of water to resist against—require walls of less thickness than those of large dimensions. Under ordinary circumstances, for a tank of 37 feet diameter and 16 feet deep, the base of footings should be 3½ bricks wide, with offsets on the outside for 5 or 6 courses, when the wall of the tank commences; which should be 2½ bricks thick at bottom, diminishing by two offsets on the outside to 1½ brick thick at top, terminating with a stone coping, or, when strict economy is necessary, a coping of brick on edge.

For a tank 100 feet diameter and 25 feet deep, the walls should be 4 bricks thick at bottom, diminishing to 2½ bricks at top; the footings being 6 bricks wide at base, gradually diminishing, as before stated, to the course where the wall commences. Piers will also have to be carried up from the footings in order to receive the holding-down bolts by which the guide-columns or standards are secured.

When building a brick tank, as far as practicable, the whole of the sides should be carried up uniformly, and the piers for the standards well bonded with the wall. The whole of the bricks, as already observed, should be good, hard, well-burnt stocks, and thoroughly saturated with water previously to being laid. The importance of having the bricks well wetted can not be overrated when good, sound, and strong work is desired.

Roman cement, which at one time was used for hydraulic work, is now no longer employed, for the simple reason that it sets with such rapidity as not to give the requisite time to work it properly. Most of the common mortars, when in contact with water, will dissolve by degrees, become soft, and in time the joints will be imperfect, and the destructive power of the water will soon show itself on the brickwork; therefore cement or hydraulic mortar must be employed. The best material of all for mortar for hydraulic work, is undoubtedly Portland cement, mixed with two or three times its bulk of good clean sand. This cement, when entering into the formation of concrete, will set under water, supposing this to be still; hence, when making foundations, the concrete can be thrown into an excavation containing water with every assurance of its hardening. Another quality of Portland cement is that with time, it increases in hardness, until at the end of a year or so, it becomes considerably harder than many descriptions of stone. Lias lime makes also a good hydraulic mortar. Also a natural production from Italy, called puzzolana, resembling in appearance, when in powder, the red oxide of manganese, is very excellent for rendering ordinary lime hydraulic. Previously to being used, the puzzolana should be ground to a powder, and mixed in the proportion of one of that to three or four of lime slaked, and the corresponding quantity of sand, to be made into mortar.

Puddle is formed of plastic clay, and is sometimes prepared by men treading upon it repeatedly, and moistening it with water; but by the most improved method it is prepared with a pug mill. When puddle is used, on the excavation being completed, the whole of the area of the bottom is covered to a thickness of about 12 inches of that material; which, after being properly levelled, the brickwork is commenced thereon. The spaces for the piers also are considered in the excavation.

In the construction of a brick or stone tank, whether with or without puddle, the footings of the walls and piers are first laid, and upon these the wall is carried up as described. When economy is considered, the top of the tank is finished by a course of bricks on edge, which for all purposes is all that is required. However, many engineers go to the useless expense of stone for coping, as well as for the foundation of the standards. Where money is abundant there can be no objection to that luxury; but when this is not the case, brickwork alike for the top of the piers, and building in the holding-down bolts, answers every purpose.

In carrying up the brickwork of the tank, the puddle is placed in a uniform thickness against the outer side of the wall, and as the space between the puddle and the solid ground becomes wider, this must be carefully filled in with earth well rammed in thin courses, corresponding with the progress of the wall and puddle. In some very small works the dry well containing the inlet and outlet pipes is dispensed with, and the side of the tank is built with a small recess sufficiently deep and wide enough to receive the pipes, which are placed close to each other and provided with their corresponding syphons. This system is more economical than the other, but possesses some disadvantages, among which is, that in the event of the pipes becoming obstructed they are not so readily cleared as when the dry well exists.

The duration of a tank will materially depend on the perfection of the brickwork; but when properly constructed, a tank may be pronounced practically everlasting.

As some guide to the cost of brick tanks, it may be observed that brickwork is generally measured by the rod of the standard thickness of 1½ bricks, of which 272 feet superficial make a rod; therefore, whatever may be the thickness of the walls, it will have to be reduced to the standard, and estimated accordingly. The price of concrete walls with one-eighth Portland cement is £10 per rod. The brickwork in Portland cement may be estimated at £20 per rod, and, with due care, by observing the preceding instructions as regards wetting and embedding the bricks in the mortar, a sound tank may be assured by any ordinary good bricklayer.

The following, taken from "Richards' Treatise" is an

Abstract of a Specification of a Gas-holder Tank 33 *feet* 4 *inches in diameter and* 12 *feet* 3 *inches in height, suitable for a holder* 32 *feet in diameter and* 12 *feet deep at the sides, capable of containing* 9,500 *cubic feet of gas, including seal of six inches.*

"The ground to be excavated in the place indicated, of a diameter of 38 feet, forming an annular space of 4 feet wide, perfectly level, and 12 feet deep, leaving a dome in the centre of 30 feet diameter at base and 7 feet high in vertical section. The excavation to have sufficient slope to prevent the ground slipping, or, if necessary, to be shored in such a manner as not to interfere with the progress of the building. The excavation for the dry well to be made at the same time, also a communication between this and the tank for the purpose of placing the inlet and outlet pipes which will be done before the concrete of the centre is laid. The excavation to be kept clear of water during the construction.

"*Concrete.* A bed of concrete, 12 inches thick, to be laid around the outer part of the excavation and levelled, and to be continued over the whole of the dome a like uniform thickness throughout. The concrete to be formed of seven parts of clean ballast and gravel with one of Portland cement, the whole to be thoroughly mixed.

"*Brickwork.* All the bricks to be hard, well-burnt stocks, and each brick to be thoroughly wetted just previous to laying and embedded in the cement, so that all the joints are flushed or filled, to be laid in Portland cement and clean sand mortar, in the proportion of one of cement and three of sand. The concrete of the annular space being levelled, a course of footings for the wall of the tank of three bricks wide, also for the four piers of three and a half bricks square, will then be laid, the internal diameter of this being 32 feet 8 inches. On these footings the wall of the tank is then commenced, of an internal diameter of 33 feet 4 inches, and carried up two bricks thick to a height of 7 feet 6 inches. At this point the wall will be diminished to one and a half brick thick for a height of 12 feet, on which a course of bricks on edge, 16 inches in width and projecting 2 inches beyond the outside of the tank, are to be laid perfectly level over the whole of the top of the wall. The four piers to be each three bricks square at base, tapering to two and a half bricks at the top of the wall, to be bonded with the wall from bottom to top. At the height of 7 feet 3 inches four cast-iron washers with the holding-down bolts will be built in each of the piers, the holding-down bolts being supported by wooden templates, having holes corresponding with those of the bases of the guide-columns, care being taken that they are exactly equidistant and at the proper height and level with each other. A course of flat tiles will be set in cement over the annular space around the dome. On the centre of dome there will be a dwarf pier of 3 feet high, two bricks square at base, and one and a half brick square at top, for the purpose of supporting the centre pipe of holder when down.

"The ground to be filled in behind the wall and rammed as the work progresses, care being taken not to injure the brickwork. The tank, when completed, to be a true cylinder, and perfectly plumb at the sides. The walls, as well as the centre dome, to be afterwards rendered with neat cement to a thickness of not less than ¼ of an inch, and to be worked with the trowel so as to form a smooth surface.

"To construct a dry well adjoining the tank of 3 feet 6 inches internal diameter to the depth of 13 feet, the footings of wall to be two courses of one and a half brick, and on this the wall will be built of one brick thick, set in hydraulic mortar to the height of the ground level, where it will be finished by a course of bricks on edge, set in Portland cement and sand.

"All surplus earth to be carted away, and the ground left level as before the commencement of the work."

In the preceding some idea of the method of constructing brick tanks without puddle is given. As our space is necessarily limited, we intend only to furnish abstracts from specifications. A form of the general conditions, of contracts between a gas company and contractor, by Mr. Wyatt, is given hereafter.

STONE TANKS.

Where stone is abundant, tanks can be constructed economically with blocks of about the size of large paving-stones, built in hydraulic mortar, backed with rubble masonry, the walls being rather thicker than when built of brick. A perfectly sound tank can be so constructed without puddle, the only precaution requisite being, to well moisten the stones and embed them in the cement or mortar, as indicated already in the construction of brick tanks.

When the ground is soft it is cheaper to make the centre nearly flat; but should the foundations be under water then the mound in the centre has an advantage, as it avoids excavating, concreting, or puddling in the water.

In some localities neither puddle nor bricks are to be obtained, when recourse must be had to the building material of the country; and this, in some of the islands of the Mediterranean and elsewhere, consists almost entirely of freestone, which serves alike for walls, roofs, and often flooring, thus replacing bricks, tiles, and boarding. In such places a more suitable material for gas-holder tanks can only be procured at a most extravagant cost; nevertheless, even with this, a good and sound tank can be constructed without the aid of puddle.

For this object the stone is obtained in suitable blocks and faced to the required curve, the foundation or flooring being composed of concrete; the wall is built with Portland cement or other hydraulic material, such as lias lime or ordinary lime mortar intermixed with puzzolana, well backed with rubble. When the tank is finished the whole of the interior is "rendered" with (by preference) pure Portland cement, a thickness of about ⅜ of an inch, which is well flatted with the trowel; or, supposing all the joints of the wall to be pointed, two or three coats of hot thick tar over the whole surface will stop all the pores of the stone and make the tank sound. With good close-grained stone there is no difficulty whatever in making a tank perfectly sound without puddle; and it is highly desirable that this should be the case, inasmuch as in localities where stone abounds, as a rule, plastic clay is scarce.

No matter the kind of tank that may be required, whether stone, brick, or concrete, we have always found it the surest and the simplest method, to fix at the centre point a post, to which is attached a rod of a length equal to the radius of the tank. This rod is so arranged as to revolve with facility, and at its extreme end is a plumb-bob, by which the exact positions for the templates corresponding with the curve of the interior of the tank are adjusted. Thus with 2 wooden templates, each of 8 or 10 feet in length, corresponding with the curve of the holder, by the aid of the plumb-bob the work is carried out with every certainty, and by it may be proved at any stage.

When building stone tanks the centre part, as well as the foundation of the walls, are generally formed of concrete, of from 9 to 15 inches thick, according to the diameter of the tank; the only precaution necessary is to have a sufficiency of liquid cement, in order to fill all the interstices between the ballast and gravel, and to have all the material clean and well intermixed with the cement, or hydraulic mortar, that may be employed. The centre is afterwards "rendered" with cement or hydraulic mortar.

The footings are then commenced, the face of the wall being formed of stones dressed on five sides, thus presenting a good face for the interior of the tank, and offering four good surfaces for the joints. The wall is then backed with rubble to the required thickness, but all the stonework, whether faced or rubble, should be wetted at the moment of laying, and all the joints on the face of the wall should be pointed.

Generally it is preferable to place the inlet and outlet pipes in their positions, with their corresponding syphons in the dry well, in the act of laying the concrete for the foundations of the tank. By these means a great deal of trouble which is incurred when holes are left for the pipes, is avoided.

Stone tanks will vary in price according to the site, and the price of stone; but we believe that, except under extraordinary circumstances, an average of about £12 per 1,000 feet tank may be taken as their cost.

COMPOSITE TANKS.

With the view of avoiding the expense attending the construction of the sides of gas-holder tanks of brickwork, particularly in localities where ballast can be obtained at a reasonable rate, some engineers have introduced the composite system. This consists of forming the facing of the wall of brickwork, which is backed to the desired thickness with concrete; originally there was an inner and outer facing of brickwork, according to the thickness of the wall, and the intermediate space was filled with concrete.

These kinds of tanks have been erected at some of the largest gas-works in the kingdom, but it must be observed that they are invariably puddled, which literally means that reliability cannot be placed on the structure to retain water, without the aid of that material. But we are of opinion that with modern experience and the excellent building materials such as Portland cement and lias lime at our command, every tank should be built in such a manner as to be impermeable without the aid of puddle, which in some localities is very expensive, and at times it cannot be obtained at any reasonable price.

A composite tank was constructed by Mr. Livesey, at the South Metropolitan Works, London, of 153 feet in diameter and 38 feet deep in the clear. The wall of this is 4 feet 3 inches thick at the bottom, diminishing to 2 feet 3 inches at the top, including bricks and concrete. The whole area of the bottom, as well as beneath and outside the wall, is puddled. The saving effected in building this tank by using concrete instead of brickwork was £1,700, and there is every reason to believe that, in addition to the economy, the former is stronger than the latter.

CONCRETE TANKS.

In some localities, where ballast and shingle are abundant, the most economical tank is that formed entirely of concrete, which construction has been recently adopted at works of the largest magnitude. We may also observe that during the last few years concrete walls and buildings have become of very general adoption, and it would not be flattering to the intelligence of gas engineers, if they neglected the use of this material in the formation of tanks.

The merit of making the first concrete tank is due to Mr. Douglas, of Portsea. The system employed by that gentleman is as follows. The excavation being made, a layer of concrete of the desired thickness is placed so as to form the footings of the wall, which being perfectly levelled, the wall is commenced. For this purpose there are a number of moulds, of which a portion is made to the curvature of the interior of the tank; another like number to suit the exterior; whilst others are made corresponding with the piers. These moulds are formed of stout boards of say 9 feet in length and 2 feet in breadth, placed in a vertical position and parallel to each other in the exact locality where the wall is to be built. They are separated from each other a distance equal to the thickness of the intended wall, but secured from farther separation by bolts and nuts. These being arranged, the concrete is carefully placed therein in such a manner as to avoid air pockets or spaces in the wall, and in the course of two or three days, on the concrete becoming set, the frame is detached by unscrewing the nuts and removed to another part, after which the bolt-holes are securely closed.

But in the meantime the other parts of the wall are constructed with other moulds, so that the men employed (who, when compared with those required for a brick tank, are few in number) are constantly engaged from the commencement to the termination of the tank. From this it is obvious that an ample number of moulds is necessary, in order that no delay may occur in the work. The lower course around the tank being completed, which we have assumed to be 2 feet high, together with the commencement of the piers, the moulds are placed for the second course, which is carried out precisely in the same manner as the preceding. However, the precaution has to be observed, that when building, previous to laying fresh concrete against that already set, the latter should be well wetted, as already indicated in building stone and brick tanks, in order that the fresh concrete shall adhere to the other.

One of the most interesting structures of the kind under consideration is the concrete tank with its corresponding holder lately erected by Mr. Valon at Ramsgate. This tank is 112 feet in diameter and 26 feet deep, formed entirely of concrete rendered with Portland cement and sand, in the proportion of one of the former to two of the latter. The excavation is annular, and in chalk, to within 11 feet of the top of the tank, at which point the whole of the ground is removed, thus leaving a cylinder or "dumpling" of about 102 feet in diameter and 16 feet deep in the centre of the tank. The concrete consists of three of ballast, two of sand—both clean and free from dirt —and one of Portland cement. The outer wall averages

2 feet thick, but the part above the chalk is supported by three iron bands 6 inches by 1 inch, placed at equal distances and filled in solid with the concrete. The inner wall averages 18 inches thick. Both walls, as well as the top of the dumpling, are rendered with cement as stated.

The method of construction differs materially from that already described, for instead of employing a number of moulds, a wooden framing was made exactly corresponding with the interior of the wall of the tank, and one half its height. This was fixed in its position, when the concrete as prepared was thrown into its place. On the lower half being completed the framing or walling was then removed and adjusted to the upper half of the tank, when the concrete work of the outer wall was completed. The inner wall was formed in a similar manner. This tank is perfectly sound, and is in every sense an excellent structure and cost £3,500.

We may remark that the holder of this tank is telescopic, having two lifts rising to a height of 52 feet, and contains 500,000 cubic feet. There are fourteen standards and two tiers of lattice girders, all of wrought iron. The roof and sides are strongly trussed as we had occasion to observe in the course of erection, while the thinnest sheets employed are No. 12 B W gauge. The whole is of excellent design, very substantial in all its parts, and cost, including the iron hoops for the tank, £5,500. Thus Mr. Valon possesses the merit of having constructed the cheapest gas-holder and tank on record, which cost at the rate of £18 per 1,000 feet, or 4·3d. per cubic foot. This apparatus has been in operation some months, and leaves nothing to be desired, and considering its capacity, it is second to none.

Another tank of still larger dimensions, namely, 184 feet in diameter and 47 feet deep, has been constructed by Mr. Livesey, also entirely of concrete, without a brick or stone in the ordinary sense of the word, or a foot of puddle entering into the whole of the immense structure, which has been in the main successful; and but for the undue haste observed in bringing it into active operation, it would have been all that could be possibly desired. Therefore if puddle can be successfully dispensed with in a work of this magnitude, it is certain that it is not necessary in tanks of smaller dimensions.

The success of a concrete tank depends on the care observed in the operation of construction; and the principal points are, to have the sand, ballast, or shingle free from dirt and earthy or clayey matter. Whether the sand be sea or river does not matter, but it must be clean, and if granulated the better. The quality of good Portland cement, and the proportions for concrete as defined by Mr. Wyatt, the constructing engineer of the Gas-light and Coke Company, are as follows:—

"The cement not to weigh less than 112 lbs. per imperial bushel, and to be tested from time to time by those in charge of the work, for cohesive strength and setting properties. There must be a cohesive strength in the pure cement of more than 200 lbs. per square inch, after seven days' immersion in water, and 500 lbs. after one year's immersion.

"The whole of the concrete to be composed of 1 part of Portland cement as above, and 7 parts of gravel measured dry and net. The gravel to be composed of 5 parts of coarse screened stones, up to 1½ inch diameter, and 2 parts of sand."

The ballast from the sea-shore is the most suitable for the purpose, on account of its freedom from dirt. Sea sand for building dwellings is not desirable, because it retains a portion of salt, which shows its presence in wet weather by the walls becoming damp. This, however, in a gas-holder tank is not to be considered.

A concrete tank is liable to much greater variation in its cost than any other description, and will mainly depend on the price of Portland cement and the ballast. We believe they ought, under favourable circumstances, to be erected at about £8 per 1,000 feet capacity.

When entering into the description of the construction of a concrete tank, Mr. Douglas gives some details, in which he says, "Throwing the concrete from a height should be avoided, because the elements of the concrete, having different specific gravities, fall in a heap together, and the cement is thus separated from the other material." We are of opinion that the defect of this arises from the liquid cement being ejected from the mass when falling on the ground, by which the concrete is rendered porous. We also differ on another point from that gentleman, when he asserts that, "concrete will leak like a colander."

In our opinion, the degree of impermeability of a mixture of cement and sand will depend on the freedom of the latter from any foreign matter; for it being conceded that pure cement is not porous, it follows that, if intermixed with powdered glass, then both on account of the cohesive affinity existing between the two substances, as well as their nature, the compound will be as impermeable as the pure cement. If, again, the cement be intermixed with perfectly clean sand (and if granulated all the better), the mixture will be found equally desirable for the object. This is not only correct in theory, but is confirmed by experiments made with the view of determining a point upon which much diversity of opinion exists.

To this we may add that in an experiment made to test the suitability of concrete for a tank, we made one of small gravel and cement of about ½ an inch thick, 8 inches high, and of a like diameter. This was filled with water, and remained perfectly tight during several months, which in our opinion settles the question. However, it must be admitted that engineers have been very cautious in introducing any improvements into the construction of holder tanks, and when the risk is duly considered it is not surprising. Nevertheless, concrete tanks of the largest magnitude are made, and one is now in the course of construction at the South Metropolitan Gas Works for a holder of five million feet; but whether they can be made sound when erecting, or whether they require to be afterwards rendered, does not materially affect the expense.

Cast-iron Tanks.

When the tank is made of cast iron, the pieces of which it is composed are usually plates about 4 feet 6 inches long and 3 feet 6 inches deep, having flanges all round them of 2½ or 3 inches wide. The flanges are cast with holes about 6 inches apart, to receive the bolts used for fixing the plates together. The plates vary in thickness according to the dimensions of the tank for which they are intended. In large tanks, from 80 to 150 feet in diameter, the bottom is formed of plates varying from 1½ to 1 inch thick, and the side plates vary from 1⅛ to 1 inch thick for the bottom tiers, and from ¾ to ⅝ inch thick for the top tiers. The plates for smaller tanks are thinner than those stated; for a tank 25 feet diameter and 10 feet deep they are not required thicker than ⅝ inch for the bottom and lower tier of sides, and ½ inch or less for the top tier. In all cases it is essential to place iron bands or hoops around the exterior, which are made secure with cotters, as without these the soundness of the tank cannot be assured.

A case recently occurred where a holder with a cast-iron tank of about 80 feet in diameter and 20 feet deep, after being completed and in action for a few days, the tank suddenly gave way and the whole became a complete wreck; at the same time the gas was ignited by some light in the vicinity, and burnt with an immense flame for a minute when the town was put in darkness. Fortunately there were other holders, although not in action at the time. The cause of this accident was the weakness of the hoops, and these giving way, the tank by the force of the water was broken into innumerable pieces, and a low wall demolished.

Iron tanks are made of various sizes up to 150 feet in diameter, but seldom more than 25 feet deep. The columns or standards for guiding the holder, are generally attached to brick piers by means of holding-down bolts built therein, which piers are separated from the holder, in order that any settlement that might occur with the one would not affect the other. For very small holders, brackets for carrying the columns are cast on the tank, and the columns are connected together at the top by **T** iron girders.

When cast-iron tanks are erected, they require a suitable foundation of concrete, which should be made perfectly level, and the bottom plates securely embedded in the mortar. Sometimes baulks of timber placed transversely are used instead of concrete; but as these are likely to be destroyed by rot, on this account concrete is decidedly preferable.

The flanges of the bottom plates are always inside the tank, which offers great facility for bolting and caulking the joints. The flanges of the sides are generally on the outside, but sometimes, although rarely, for the sake of appearance, they are placed inside the tank. This, however, is very injudicious, for in this case, in the event of a plate breaking or a joint leaking, after the holder is in operation, it is very difficult to repair.

The following specification will clearly describe the manner of constructing the vessels under consideration:—

Specification of a Cast-iron Tank for a Gas-holder 40 *feet in diameter and* 12 *feet deep.*

"The tank to be 41 feet in diameter and 12 feet deep to top of internal flanges on the bottom plates, internal measure, and to be constructed as follows:

"The bottom to be formed of four rings of plates, with a centre plate 3 feet in diameter by ¾ inch thick. The first row next to the centre plate to be 4 feet 4 inches long, by 3 feet 1 inch wide at the outer end, by 10 inches at the inner end, and 11/16 inch thick of metal. The second row to be 4 feet 10½ inches long, by 2 feet 11 inches wide at the outer end, by 1 foot 7 inches wide at the inner end, and 11/16 inch thick of metal. The third row to be 4 feet 10½ inches long, by 3 feet wide at the outer end, by 2 feet ½ inch at the inner end, and 11/16 inch thick of metal; and the fourth row to be 3 feet wide at the outer end, by 2 feet 3 inches wide at the inner end, and ¾ inch thick, and to be 4 feet 10½ inches long from the inner end to the inside of flange on the outer end; this outer flange to project 3 inches above the plate and to be curved so as to coincide with the radius of the tank. On the top of this flange is to be formed the flange for bolting to the bottom ring of side plates, thus:

"The whole of the bottom plates to have flanges ⅝ inch thick cast on them, and projecting 3 inches above their upper surface, and provided with ¾ inch square holes for bolts placed 6 inches apart from centre to centre, also brackets ⅝ inch thick between the bolt-holes. Each flange to be set back 3/16 inch from the edge of the plate so as to leave a space of ⅜ inch for jointing.

"The plates to be bolted together by bolts ⅝ inch thick, square under the head, with strong hexagonal heads and nuts, and provided with 1⅛ inch washers, the joints to be made with ordinary iron cement, well caulked in from the inside.

"The sides of the tank to be formed of three tiers of plates, each tier consisting of forty-three plates 4 feet high and 3 feet wide, and truly curved on the inner side to a radius of 20 feet 6 inches.

"The bottom tier to be ¾ inch thick, the middle tier 11/16 inch thick, and the top tier ⅝ inch thick. Each plate to have a flange ⅝ inch thick, cast in each of its four sides, and projecting 3 inches beyond its outer surface, with ¾ square holes for bolts placed 6 inches apart from centre to centre, and intervening brackets ⅝ inch thick between all the bolt-holes. The outer extremity of these flanges to have chipping pieces cast on them 3/16 inch thick, the thickness of the plate, so as to leave a space of ⅜ inch for jointing.

"These, like the bottom plates, to be bolted together by bolts ⅝ inch thick square under the heads, with strong hexagon heads and nuts, and provided with 1⅛ washers. The joints to be made with ordinary cement, well caulked from the outside.

"The bolt-holes must be cast on the flanges in such a manner as to coincide exactly with each other, without chipping or enlarging when the plates are fitted in their respective places. On the outside of the bottom and middle tier of the side plates, and at a height of 2 feet above their lower edges, a rib of flange is to be cast 3 inches wide and ⅝ inch thick, with brackets on each side ⅝ inch thick and 6 inches apart. These ribs are intended to form a continuous and level bearing around the outside of tank for the wrought-iron hoops. The vertical flanges at the points where these ribs intersect them to have projections cast thereon, for the purpose of supporting the wrought-iron hoops.

"These hoops or belts to be three in number, one 4 inches broad and ¾ inch thick, for the bottom tier of the plates, and the others 3 inches broad and ⅝ inch thick for the remaining tiers. Each belt to be provided with three joints or couplings, in no part of less strength than the body of the belt, and with cotters of the same thickness.

> Each section of these belts to be in two pieces, which are to be connected by a fish-plate 18 inches long, and of the width and thickness of the respective belts, and riveted thereto by ¾-inch rivets, at 2 inches apart from each other.
>
> "In the centre of one of the plates, forming the centre row of bottom plates, a hole 5 inches in diameter to be cast for the inlets, and in the centre of the adjoining plate a hole 6 inches in diameter for the outlet pipe. Each plate for a space of 3 inches round the hole to be made ¾ inch thicker than the rest of the plate.
>
> "The whole of the plates to be fitted together and plainly marked for fixing in their respective places, and to be painted with a coat of metallic oxide paint previous to delivery. The whole of the material herein specified to constitute a tank, which, when erected, shall be truly cylindrical and of the dimensions given."

The total weight of the tank thus specified is 57 tons 7 cwt., of which about 52 tons are cast iron; the rest, comprising the hoops, bolts, and nuts, are of wrought iron. On supposing, therefore, the former to be £8 and the latter £18 per ton, the price delivered would be £512. To this must be added carriage, say 20s. per ton, and estimating the expense of preparing the ground and erecting the tank to be £60, its total cost would be about £630.

Cast-iron tanks cost about from £25 to £33 per 1,000 feet capacity of tank; therefore their high price only permits of their being adopted under exceptional circumstances.

COMPOUND TANKS.

Tanks which are constructed with the outer wall or sides of cast iron, and the centre part of clay, concrete, or other material, are called compound tanks, but however desirable they may be in certain localities, they are seldom adopted.

There are certain localities where the site is of good plastic clay and is thoroughly impermeable. An instance of this occurs at the Pancras station of the Gas-light Company, where, in a tank of 145 feet in diameter, at a depth of 32 feet the clay only is relied on to retain the water. This, however, cannot be surprising when we reflect on the amount of confidence there always exists in puddle, which is frequently placed a thickness of one foot only; and this is depended upon to remedy all the evils of imperfect workmanship.

In localities like that in question, the greatest facilities are afforded for the construction of a compound tank, the ground of the interior of which may be left in its natural state, when the wall of cast iron only would be required. When constructing a compound tank in a plastic clayey soil, the excavation is made to the desired depth and diameter, and made perfectly level at the circumference. The sides of the tank are formed of plates bolted together, and cemented as already described. The bottom of the lowest tier is provided with a broad flange and placed in its exact position on a bed of puddle. Afterwards, when the whole of the circle of all the different tiers of plates is completed, and properly bolted and cemented, the whole of the flange should be well puddled on the inside and outside, which would retain the water with all certainty.

Mr. G. W. Stevenson constructed a tank of the description in question some years ago, in which the foundation for the sides was formed of dressed stones, properly levelled; in these was cut a channel of about 3 inches deep and the same width, in order to receive the bottom plates of the side. The bottom row of plates being bolted and cemented, the channel was afterwards filled with pure Portland cement which made a perfectly sound joint.

In order to appreciate more fully the value of this method of construction, let us assume that in a certain locality it is required to build a tank, the whole or the greater portion of which shall project above the level of the ground, which may be occasioned by any of the various circumstances already referred to. Now as the average areas of the interior of tanks are equal to the surface of their walls, and as the plates for the former are thicker than the latter, it follows that the centre contains a greater weight of metal than the walls, and when we come to tanks of great diameter and shallow depth this variation is very important, as we find in a tank of 150 feet in diameter and 22 feet deep that the surface of its central area is about 70 per cent. greater than that of the walls. Hence, under these conditions, it becomes simply a question of the price of iron against the other building material which may be employed to replace it; and if we suppose this to be Portland cement concrete, adapted to a tank of large dimensions, say 150 feet in diameter, it would have a thickness of 15 inches, and when rendered with pure cement would cost about 9s. per square yard. On the other hand, the weight of a square yard of plate for a similar description of tank would be about 6 cwt., costing about five times the price of the concrete. Thus, under these circumstances, by the adoption of the compound tank of the diameter stated, instead of forming the whole of cast iron, an economy will be effected under average conditions of upwards of £1,700. In addition to this there is the other consideration that the whole of the concrete work could be executed by ordinary labourers, which in certain localities abroad, where skilled labour is difficult to obtain, is a further recommendation.

In impermeable clayey sites, the price will be considerably less, and often compound tanks will not be more costly than those of brickwork or masonry; of course, everything depends on the price of bricks, transport, and sometimes the customs duties, will prevent iron being adopted.

ANNULAR TANKS.

Annular tanks have been constructed of brickwork; but in all cases they are very expensive. They have also been made of wrought iron, but only under extraordinary circumstances have they been adopted. One of these was built at the station of the Surrey Consumers' Company at Rotherhithe, the necessity for which arose from the very unstable nature of the ground. The site of these works immediately adjoins the river Thames; the soil is loose sand, through which the water percolates with facility at a depth of 12 feet from the surface. The engineer, Mr. Finlay, after duly considering the unstable nature of the site, and the flexibility of wrought against cast iron in the event of any settlement, decided on forming the tank in segments, thus confining the operations to a limited area, and the whole was successfully accomplished. A remarkable feature in this structure is that the entire of the central area is rendered impermeable by puddle alone, which was transported to the locality. Annular tanks may also be adopted with economy in localities such as Ramsgate, where the site is composed of chalk, and the expense of excavation would be excessive. Under these conditions it will be often cheaper to build the inner wall than excavate. A cast-iron annular tank existed for many years at the late City of London Company's works. They are, however, always expensive, unless of very large diameter and shallow depth, and should only be employed when rendered absolutely necessary by the nature of the site.

GUIDE COLUMNS, STANDARDS, AND GIRDERS.

Whatever may be the description of tank constructed—whether of brickwork, masonry, or iron—it is necessary to erect suitable guide-columns, or standards, to guide the holder, and of sufficient stability, in order to prevent it from being blown over by the wind. With tanks sunk in the ground, the piers for supporting the guide-columns are provided for in the foundations, and are carried up from those points, and when within a few feet from the top of the tank the holding-down bolts are built into the piers in such a manner, that the base plate of each column is secured with corresponding nuts.

The guide-columns are generally cylindrical and of cast iron, as shown in drawing, page 208, and are braced together at the top, and sometimes midway, by girders, which are either of cast iron or wrought iron, or a combination of the two, and on which the ornamentation of a gas-holder principally depends.

In many of the gas-holders of modern structure the standards are of wrought iron and trussed. But whether cast or wrought iron be employed, each of the columns is provided with a guide rib which extends the whole range of the holder, alike in single as in telescopic holders.

With cast-iron tanks the piers are carried up separate from the tank, in order that any settlement that may take place in one will not affect the other.

The following is a copy of the conditions drawn up by Mr. Wyatt for the construction of a gas-holder tank which is applicable to most descriptions of work:—

Conditions.

"The contract is to include the provision of all materials and labour for completing the works shown on the drawings and described in the specification.

"The contractor must set out the works, and must satisfy himself as to the accuracy of the same, as he will be responsible for any error in the form of the works.

"The works are to be performed under the control and supervision of the engineer, or such person or persons as may be appointed for such purpose, and whose decision upon all matters will be final. All orders for new or altered works will be made in writing by the engineer.

"All materials delivered by the contractors upon the site of works to become the property of the company, and shall not be removable without the engineer's consent. All materials disapproved of by the engineer shall be removed from the site of the works within forty-eight hours of the contractor receiving notice thereof from the engineer.

"In case the company shall consider it desirable to alter any portion of the work, adding to or diminishing the amount thereof, or changing one kind of material for another, the same shall be executed under the conditions of this specification, and measured up and paid for at the schedule of prices annexed hereto, or, where no price is affixed for the work, the same shall be valued by the engineer, whose opinion thereon shall be final. The value of such works shall be accordingly added to, or deducted from, the amount of the contract.

"The contractor will be required to furnish a monthly statement to the engineer of all extras or departures from the contract, and a monthly stock account of all materials delivered by the contractor upon the works.

"The contractor must guarantee the company harmless against all accident or damage to the company's property or works, or the properties and works of others, during the progress of the contract, and incident thereto.

"Should the progress of the works not be deemed satisfactory at any time by the engineer, he may take the works in hand and use the contractor's plant and materials on the ground, and deduct the cost of such proceedings from any balance due to the contractor. Such operation on the part of the engineer shall not relieve the contractor from any liabilities under the contract.

"The contractor shall maintain and uphold the works in an efficient state for twelve months from the time of completion, as certified by the engineer, and shall then hand them over to the company sound and efficient, making good all defects, accidents, and damages during such term. Any reparation performed by the company during the maintenance, in consequence of the contractor failing to do so, shall be charged to the contractor.

"All measurements for quantities and estimates will be based upon the net dimensions shown on the drawings.

"Payments will be made monthly upon the amount of work performed during the preceding month, equal to 80 per cent. of such work done and certified by the engineer, and the remainder will be retained as a drawback or security for the performance of the works. Half the drawback will be paid within three months, and the remaining half within twelve months of the certified completion of the works by the engineer.

"The contractor to find two sureties for the proper performance of the contract in the sum of £ .

"The work to be completed by the ——, and in default thereof the contractor will allow a discount off the gross amount of the contract of per cent. for each month the works remain unfinished.

"A sum equal to half per cent. on the contract amount to be included in the tender for the taking out of the quantities attached in this specification."

THE GAS-HOLDER.

There are two kinds of gas-holders, the one called the single lift, and the other the telescopic, hereafter to be mentioned. The single lift consists simply of a cylindrical vessel in the tank as already described, and represented in

Fig. 38, of which a quarter part is removed in order to show one of the pipes and the manner the roof is supported. The stand-pipe well is shown in section, with one of the two pipes with its syphon at the bottom. The holder is about 42 feet in diameter and 16 feet deep, and has six cast-iron columns, which serve for guides for the rollers on top of the holder. The columns are attached to each other at the top by cast or wrought iron girders.

The holder, when raised by the action of the gas, has very little strain upon it; and only when empty, or when it touches the ground, do the roof and sides require any support. For this object, roofs are sustained generally by "trussing." This trussing consists of a series of radiating bars of T or flat bar iron, diverging at equal distances from the centre plate, called the "crown plate," to the angle iron, or top curb, or angle of the holder. The roof is sustained by a king-post in the centre, which is supported by tension rods from the top curb; there are also suspension rods which carry struts for sustaining the centre of the radiating bars. A series of circles of bracket bars attached to the radiating bars complete the trussing of roof. The sides in large holders have also trussing to prevent the holder "bulging" or "buckling" when grounding.

In holders of great dimensions the trussing enters for a large portion of the expense; in addition, it greatly increases the weight, and in consequence the pressure, which is often by no means desirable. It is a very important consideration in the erection of gas-holders, to adjust them in such a manner that the pressure of the gas, shall not much exceed the maximum pressure required to supply the town or locality. Whenever an exhauster is not employed, an excessive pressure acts seriously on the retorts, causing a large increase in the carbonaceous deposit in them, when the production of gas is materially diminished, the gas is deteriorated in quality, while the fuel and labour are increased; and even when the exhauster is used, any superfluous pressure on the holder throws unnecessary labour on the engine, and of course requires more fuel. Therefore all small holders, particularly when there is no exhauster, should be counterbalanced in such a manner as to be enabled to give the maximum pressure required in the locality, but no more. When holders are suspended by counterbalance weights, the excess of pressure can generally be considerably reduced by placing extra weights; and in many small works, where the holder is not suspended, the loss by excessive pressure is of importance.

Gas engineers are not unanimous in opinion as to the necessity of trussing the roofs of holders. The majority adhere to the old system of trussing, whilst others dispense with it entirely. Although in the most recent construction of the largest gas-holder in the world, erected at the station of the Phœnix Company, London, and designed by their engineer, Mr. C. Woodall, the trussing for the roof is dispensed with, and on the holder grounding, its roof is supported by props situated at various points over the whole area of the tank. Without doubt this system has several advantages, being simpler, cheaper, and possessing much greater durability than when trussed; in consequence of all the iron entering into the formation composing the sheets, which are consequently rendered much thicker, than when trussing is employed.

A gas-holder 100 feet diameter and 25 feet deep, when trussed, weighs about 100 tons, and gives a pressure of about 5½ inches of water, and of this weight about 30 tons consist of trussing. Now, if we suppose a pressure of 3 inches to be adequate to supply a district, it is obvious the extra pressure must be prejudicial. In this case, if the trussing were dispensed with, the holder would be so much lighter as to give only the 3 inches pressure desired, whilst its strength and durability would be retained. There are few districts where a greater pressure than 3 inches is requisite, or at least, where the district is moderately level, and the mains of such capacity as not to demand a heavier pressure than that stated for supplying the locality. By moderate pressure, the loss by leakage, and the inconvenience and loss to gas consumers, who are unprovided with regulators, are avoided.

The thickness of plates commonly used in the construction of gas-holders varies from No. 18 to No. 11 wire gauge, the first of these being less than $\frac{1}{20}$ of an inch in thickness, weighing 1·86 lbs. per square foot, while the other is ⅛ of an inch, and weighs 5 lbs. per foot. In holders of very large diameter, the plates are required to be considerably thicker than those of small dimensions, in order to obtain the necessary pressure for supplying the district.

The pressure of gas enclosed is dependent on the total weight of the holder containing it, and on the area of its roof. The water in the tank being the resisting medium to the pressure, a quantity of this, equal in weight to that of the holder, is always displaced by the latter rising. Thus, by a knowledge of the pressure given by a holder, and the area of the top of the vessel, a close approximation to its weight may be ascertained; and, on the contrary, the weight and area being given, the pressure is readily known.

For this, and many similar purposes, the weight of a cubic foot of water, which is 62½ lbs., is the basis of calculation. Hence a column of water exactly 1 foot square and 12 inches high is equal to 62½ lbs., or a column of the same area 3 inches high, 15·625 lbs., or 1 inch high, 5·24 lbs., &c.

If, therefore, it be required to ascertain the weight of a holder, not counterbalanced, giving a certain pressure, say 3 inches when full, and the sides nearly out of the water, then, on multiplying the area of the top in feet, by the weight corresponding to a column of water of the height of pressure, the weight is ascertained. For example, a holder is 11 feet 4 inches in diameter, its area being 100 feet, giving 3 inches pressure. Then 100 multiplied by 15·625 lbs.

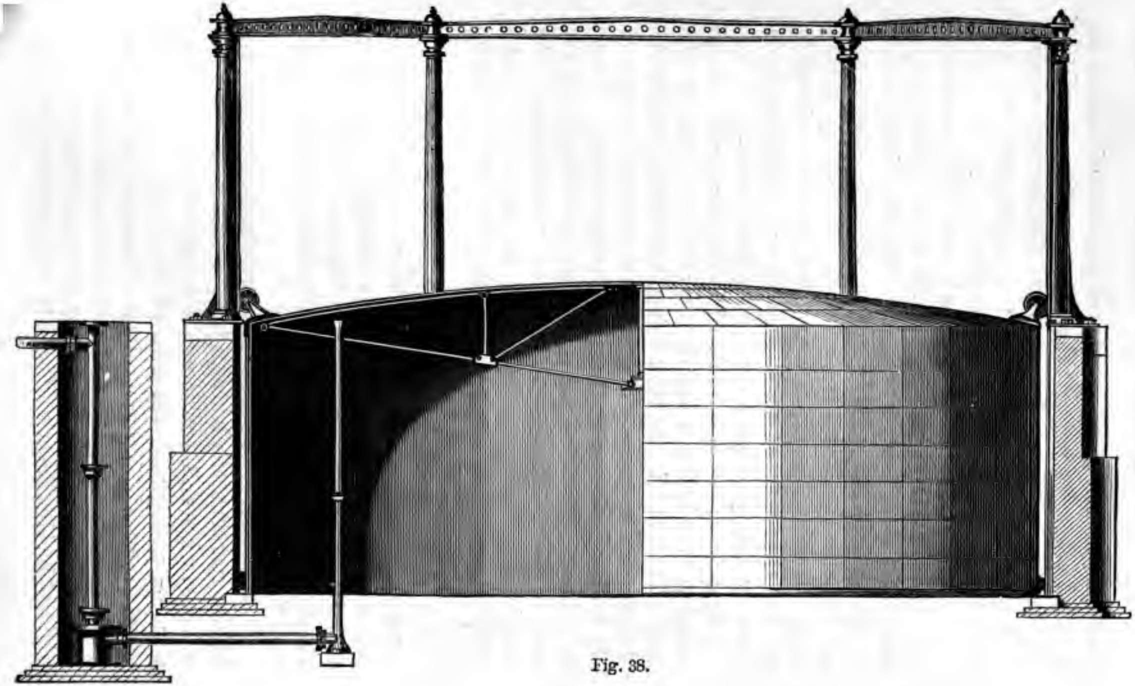


Fig. 38.

gives 1,562½ lbs. as the total weight of holder. Or, the weight being given, the pressure is calculated by dividing the total weight by the area in feet, when the weight of a square foot is found, from which the pressure the holder will give is known. Thus, reversing the figures just mentioned 1,562½ lbs. divided by 100 feet gives 15·625 lbs., corresponding to a column of water 3 inches high, or that pressure.

By the same means, if it be requisite to know the weight required to be placed on a holder to produce a certain increased pressure, then the weight of column of desired pressure multiplied by the area of top of holder in feet gives the weight. Thus, if the pressure of the before-mentioned holder requires to be augmented, say, 1 inch, that is, from 3 inches to 4 inches, then the weight of a column of 1 inch being 5·24 lbs. multiplied by the area of top, gives 524 lbs. as the necessary weight. These calculations are approximative; for them to be rigidly exact the holder should be filled with air, or an allowance made for the specific gravity of the gas. The same rule applies to the weight of governors and pressure registers.

When a holder is nearly at the bottom and its side plates immersed in water it becomes somewhat lighter, and in consequence, the pressure is less than when it is full and the sides out of the water. Many attempts have been made to remedy this, but the difference is so slight, being 2 or 3 tenths, as to render any means to prevent it quite unnecessary.

TELESCOPIC GAS-HOLDERS.

When ground is expensive, telescopic gas-holders, which are capable of storing nearly two or three times more gas in a given area than can be done by the single holder just described, are very generally used. Another advantage is that with the telescope system, the cost of the tank and holder per 1,000 feet is materially reduced.

The telescopic gas-holder consists of an ordinary single holder, called the upper lift, surrounded by a cylinder of sheet iron, similar to the side of the holder, and of about the same height. These are both immersed in the same tank, the depth of which is equal to that of the holder, or surrounding cylinder. By an ingenious contrivance, the gas on entering causes the holder to rise, and when full, lifts with it the outer cylinder, called the lower lift, elongating like the tubes of a telescope, from whence it derives its name. To effect this, on the bottom, extending around the holder, there is an annular cup of about from 6 to 9 inches wide and from 12 inches to 24 inches deep, formed by T iron and plates, represented in section by *a b c d* (Fig. 39), which, in rising, is filled with water as shown, and is called the water lute.

The surrounding cylinder, or lower lift, is about from 12 to 18 inches larger in diameter than the holder, and is furnished with a similar annular cup (*f e*), but inverted, called the "grip," and when the holder rises to the top, the inverted cup "grips" or hooks on to the water lute of the holder, thus hermetically sealing the two vessels together on the same principle as observed in the purifiers, where the means of preventing the gas from escaping from the cistern around are adopted. The holder in rising carries with it the second "lift," the two reaching a height nearly twice the depth of the tank. Sometimes the treble lift holder is employed, in which there are two cylinders or lifts, when the storage is increased nearly three-fold for the same area of tank, as compared with the single holder.

In order to insure the proper working of the two vessels together, the work is required to be executed with the greatest care. It is usual to fix on the upper edge of the lower lift a series of friction rollers, which press on the upper lift and thus make the motion uniform and prevent the escape of water from the lute. These friction rollers are usually from 4 to 6 inches in diameter, about 4 inches broad, and placed 10 or 12 feet apart all round the circumference of the lower vessel.

It is very essential in telescopic gas-holders of small diameter of 100 feet and less, that the lifts should be partially counterbalanced by suitable weights and chains, otherwise, on account of the great weight of water in the lute, the pressure is very excessive and irregular. The counterbalance weights also assist in the regular and effective working of the lift. In holders of larger diameter than that stated counterbalance weights are not employed.

In Fig. 40 is represented a large telescope holder, designed by Messrs. Dempster and Sons of Elland, such as are constructed in gas-works of the present day, which are in every sense of the term far superior to the apparatus formerly employed. This superiority in construction is, however, rendered absolutely necessary in order that the holders should always maintain a horizontal position, and prevent the water of the lutes from escaping.

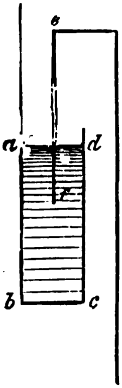


Fig. 39.

But although telescopic gas-holders possess advantages, they should not be used in very cold climates, as in the depth of winter, when a sharp frost sets in, and causes the water in the lutes to freeze, they are excessively troublesome, and require constant attention to break the ice of the lutes in order to prevent an accident. Sometimes, through neglect of this precaution, holders have been disabled and rendered useless. Another evil with telescopic gas-holders is, that when erected near the sea-shore, in a few years the action of the atmosphere destroys the plates in immediate proximity to the lute. Or it sometimes occurs that a leakage takes place in the cup of the lute, when, consequently, often a great loss of gas is sustained.

These are evils which may arise from the use of telescopic gas-holders, but their very general adoption at large

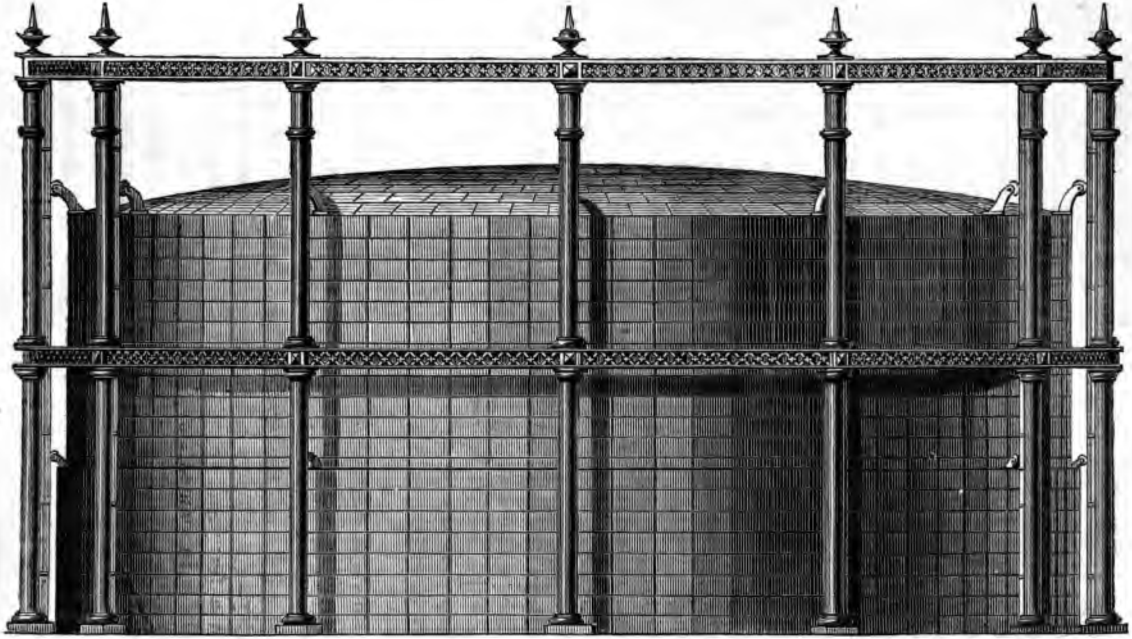


Fig. 40.

works in the United Kingdom, proves that practically no inconvenience is experienced on these grounds, and is sufficient guarantee of the excellence of the apparatus in question, and should induce Continental Gas Companies to adopt them.

Mr. Wyatt has favoured us with some particulars relating to a new gas-holder he has recently designed, which is both novel and ingenious in its construction. This is composed of a central holder 100 feet in diameter, guided by 16 strong braced standards, which are supported by eight braced girders at the top, and two tiers of ring girders. Concentric to the central holder is an annular holder of 332 feet diameter on the exterior, and 132 feet interior, thus leaving a space of 16 feet between the two holders, which admits of a framing of extraordinary strength being constructed. The holders are attached together at the top, the annular like the central, being guided by the standards mentioned. They are telescopic, rising to a height of 76 feet, and will contain the enormous quantity of five million cubic feet of gas; being, with one exception, twice the capacity of any existing holder.

According to the opinion of Mr. Wyatt, by the adoption of this system, the roof being comparatively small, the details will be of a light character, and a saving of 30 per cent. will be effected in the construction of large gas-holders and tanks. The works of that gentleman have always been singularly successful, and we are assured that this great undertaking will be no exception to the rule.

The following specifications of the material required in gas-works of three different magnitudes are extracted with permission from the "Gas and Water Engineers' Book of Reference," by Mr. George Bower, of St. Neots, Hunts, and will no doubt be found desirable, particularly by those engineers who are engaged in the construction of new, or in the alterations of old, works.

air plugs and frames, and hooks for lifting; 4 covers for inlet pipes; 2 lifting carriages and chain slings for removing and replacing covers; 1 5-inch centre change valve, for passing the gas through any three of the purifiers in succession, or through all four purifiers in succession.

Station Meter.—One station meter, capable of registering 1,500 cubic feet of gas per hour, fitted with water gauge, filling plug, &c.; 1 5-inch fourway, by-pass, and shut-off rising plug valve, to act as by-pass to station meter, and stop-valve to inlet of gas-holder.

Gas-holder.—One gas-holder, 45 feet diameter by 14 feet deep at the sides, containing 22,000 cubic feet of gas—the sheets forming the crown and sides to be of No. 15 Birmingham wire gauge thickness, excepting the top and bottom rows, which are to be of No. 14 B. w. g., with strong and suitable internal framework; 6 cast-iron guide columns, each 15 feet high; 6 trussed wrought-iron girders and bolts, to connect the tops of columns; 18 foundation bolts and 6 foundation plates; 6 guide pulleys, with carriages, adjusting plates, axles, and bolts for top of sides; and 12 guide rollers, with carriages, axles, and bolts for bottom of sides of gas-holder; 6 caps for tops of columns.

Governor.—One station governor, fitted complete; 1 5-inch fourway, by-pass, and shut-off rising plug valve to act as by-pass to governor, and as stop-valve to outlet of gas-holder.

Connections, &c.—All the necessary 5-inch connecting pipes, not exceeding 100 yards, with bends and **T** pieces for connecting the hydraulic main, condenser, scrubber, purifiers, station meter, gas-holder, and governor; also 30 yards of 3-inch pipe, with bends and **T** pieces for connecting the tar dip cisterns and from thence to tar well; 2 5-inch tank syphon boxes; 2 ¾-inch wrought-iron suction pipes.

Sundries.—One 2½-inch lift and force pump for water, with bolts and plates for fixing to wall; 1¼-inch suction and 1-inch delivery pipe with bends and connections; 1 wrought-iron cistern to contain 100 gallons; 1 1-inch supply-pipe and connections from cistern to scrubber; 1 1-inch supply pipe and connections from cisterns to retort house, with ¾-inch draw-off cock and key; 1 3½-inch tar pump, with wrought-iron clip for securing to wall; 1 swivel joint; 1 ½-inch suction pipe, chain, and shackle; 1 10-inch drain grate and frame; 2 pressure gauges, on boards, and 1 test cock with service pipes, bends, and tees.

Tools.—One set of stoking tools; 1 firing shovel; 1 charging shovel; 1 iron coke barrow; 1 galvanized iron pail; 1 2-gallon water pot; 1 pair of sight hole tongs; 1 auger for ascension pipes; 1 trowel; 1 coal hammer; 1 retort lid scraper; 2 lime sieves; 1 lime shovel; 1

brass syphon pump. To provide all bolts, pins, rivets, cement, lead, yarn, red and white lead, paint and oil, required to fix the above, and to give the whole one coat of metallic oxide paint after completion.

Total dead weight of ironwork, 45 tons.

Quantity of Firebricks, &c., required to set Retorts.—5,750 square and 850 arch bricks; 8 lumps, 26 inches by 12 inches by 6 inches; 16 lumps, 10 inches by 9 inches by 6 inches; 16 lumps, 8 inches by 5 inches by 4 inches by 6 inches; 8 pairs of flue lums; 8 lumps, 11 inches by 6 inches by 7 inches by 5 inches thick; 27 tiles, 18 inches by 12 inches by 3 inches; 10 tiles, 22 inches by 18 inches by 3 inches; 7 tiles, 17 inches by 12 inches by 3 inches; 14 tiles, 17 inches by 12 inches by 2½ inches; and 70 cwt. of fireclay. Weight of firebricks, &c., 27 tons 10 cwt.

SPECIFICATION OF APPARATUS FOR THE MANUFACTURE AND SUPPLY OF 15,000,000 CUBIC FEET OF COAL GAS PER ANNUM.

Retort Stack.—Five evaporating pans; 15 furnace bars; 5 dead plates; 5 bearing bars; 5 furnace frames with double doors; 20 shield tiles for furnace doors; 50 sight boxes and covers; 16 pilasters; 8 tie bolts; 10 holding plates for furnace door frames and 20 bolts; 5 damper tiles, with wrought-iron rods; 35 fireclay ⌓-shaped retorts, each 8 feet long by 17 inches wide by 13 inches deep, inside measures; 35 mouthpieces and 50 covers for ditto; 210 ¾-inch T-headed bolts for mouthpieces; 35 pairs of wrought-iron ears; 35 cross-bars, and 35 square-threaded T screws; 35 5-inch saddle flange pipes and bolts; 35 ascension pipes, 5-inch to 4-inch bore; 35 4-inch N pipes, with cleaning plugs; 35 4-inch dip pipes and bolts; 1 hydraulic main, 16-inch diameter of bore, and of sufficient length to receive the dip pipes from all the retorts, with ends and bolts; 6 crutched pillars to support hydraulic main.

Condenser.—One air condenser on the annular principle, consisting of 8 outer tubes, each of 21-inch external diameter and 12 feet high, and having a flange at each end, and 8 inner tubes, each of 12-inch external diameter and 15 feet high, with flange at each end; 1 top box in 4 parts, and 1 bottom box in 5 parts, with cleaning doors and bolts; 5 4-inch T pipes, with cleaning caps and bolts; 1 8-inch T pipe, with cleaning cap and bolts for inlet to condenser; 1 8-inch bend, with cleaning cap and bolts for outlet from condenser; 2 dip cisterns, each 18 inches by 18 inches by 21 inches deep, each internal tube to be provided with a damper for controlling the current of air.

Scrubbers.—Two coke or breeze scrubbers, each 3 feet 6 inches diameter by 12 feet high, fitted with 2 tiers of cast-iron grids, with wrought-iron T bearers for supporting ditto; 3 filling and discharging doors and frames, with wrought-iron ears, cross-bars, T screws and bolts; 1 water distributing apparatus, with main cock and key. Each scrubber to have also a base plate and cap; 2 8-inch T pipes, with cleaning caps and bolts for inlet and outlet; 2 dip cisterns, each 18 inches by 18 inches by 21 inches deep. To provide 1 8-inch sixway rising plug valve, arranged to pass the gas through both scrubbers at once, or to by-pass one or both scrubbers as required.

Exhauster.—One exhausting apparatus in duplicate, each part to be capable of passing 5,000 cubic feet of gas per hour, with steam engines, boilers, gearing, framework, fittings, steam and exhaust pipes, feed pumps and pipes, fly-wheels, shafts, plummer blocks, governors, throttle valves and stop valves complete; the exhausters, engines, and boilers to be so arranged that either exhauster, engine, or boiler can be shut off, or either exhauster can be worked by either engine as required. One governor, with gearing and valve placed on the gas supply pipe; 1 self-acting by-pass valve; 1 8-inch sixway rising plug valve, arranged to pass the gas through both exhausters at once, or to by-pass one or both exhausters.

Purifiers.—Four dry lime purifiers, each 8 feet by 8 feet by 3 feet deep, and fitted with 4 tiers of wood sieves or grids, resting on ledges cast on the side of purifiers, and on wrought-iron T bearers; water lutes, with wrought-iron turn-buckles; wrought-iron covers, with ground air plugs and frames, and hooks for lifting; 4 covers for inlet pipes; 2 lifting carriages and chain slings for removing and replacing the covers of purifiers; 4 wrought-iron lattice girders for carrying lifting carriages and covers. To provide 1 8-inch centre change valve for passing the gas through any three of the purifiers in succession, or through all four purifiers in succession as required.

Station Meter.—One station meter, capable of registering 5,000 cubic feet of gas per hour, and fitted with pressure and water gauges, tell-tale, indices, filling plug, &c. To provide 1 8-inch fourway, by-pass, and shut-off rising plug valve, to act as by-pass to station meter, and as stop valve to inlet of gas-holder.

Gas-holder.—One gas-holder, 70 feet diameter by 20 feet deep at the sides, containing 77,000 cubic feet of gas. The sheets forming the crown to be of No. 14 Birmingham wire gauge thickness, excepting the outer row, which is to be of No. 12 Birmingham wire gauge thickness; the sheets forming the sides to be of No. 14 Birmingham wire gauge thickness, excepting the top and bottom rows, which are to be of No. 12 Birmingham wire gauge thickness; to have strong and suitable internal framework. Seven cast-iron guide columns, each 21 feet high; 7 wrought-iron lattice girders, with cast-iron sockets and bolts for securing to tops of columns; 7 tops or caps for columns and bolts; 21 foundation bolts and 7 foundation plates; 7 guide pulleys, with carriages, adjusting plates, axles, and bolts for top of sides; and 14 guide rollers, with carriages, axles, and bolts for bottom of sides of gas-holder.

Governor.—One station governor fitted complete; 1 10-inch four-way, by-pass, and shut-off rising plug valve to act as by-pass to governor, and as stop valve to outlet of gas-holder.

Connections, &c.—All the necessary 8-inch pipe, not exceeding 100 yards, with bends and T pieces for connecting the hydraulic main, condenser, scrubber, exhauster, purifiers, station meter, and gas-holder, and 60 yards of 10-inch pipe, with bends and T pieces to connect the gas-holder and governor; also 40 yards of 4-inch pipe, with bends and T pieces, for connecting the tar dip cisterns and from thence to tar well; 1 8-inch and 1 10-inch syphon boxes; 2 ¾-inch wrought-iron suction pipes.

Sundries.—One 3-inch lift and force pump for water, with gearing and framework for working by hand or by power; suction and delivery pipes to cistern, with bends and connections; 1 wrought-iron cistern to contain 300 gallons; water supply pipes and connections from cistern to retort house, purifier house, and scrubber, with 2 draw-off cocks; 1 supply pipe and cock, with bends and connections, and 8 feed pipes from cistern to condenser; 1 supply pipe and cocks, with bends and connections from cistern to feed-pumps; 1 4-inch tar pump, with framework and gearing for working by hand or by power; suction pipe; swivel joint; chain and shackle; 1 10-inch drain grate and frame; 5 pressure gauges; and 2 test cocks on boards, with service pipes, bends, and connections. To provide the necessary pipe and fittings for gas-lights in retort house, yard, engine and boiler house, and offices.

Tools.—Two sets of stoking tools; 2 firing shovels; 4 charging shovels; 1 iron coke waggon; 1 coal waggon; 1 weighing machine and weights for coal and coke; 2 galvanized iron pails; 2 2-gallon water-pots; 2 pairs of sight hole tongs; 2 augers for ascension pipes; 2 trowels; 2 coal hammers; 2 retort lid scrapers; 3 lime sieves; 3 lime shovels; 1 2-gallon water-pot for purifier house; 1 brass syphon pump. To provide all bolts, pins, rivets, cement, lead, yarn, red and white lead, paint and oil, requisite to fix the above, and to give the whole one coat of metallic oxide paint after completion.

Total dead weight of ironwork, 140 tons.

Quantity of Firebricks, &c., required to set Retorts.—11,000 square and 2,000 arch bricks; 40 lumps, 23 inches by 9 inches by 4½ inches; 40 lumps, 9 inches by 9 inches by 4½ inches; 40 lumps, 6 inches by 4½ inches by 6 inches by 4½ inches; 40 lumps, 4 inches by 4½ inches by 4½ inches; 20 lumps, 10 inches by 6 inches by 4½ inches; 45 tiles, 18 inches by 12 inches by 3 inches; and 7½ tons of fireclay. Weight of firebricks, &c., 56 tons.

CHAPTER XII.

THE STATION METER.

The Necessity for this Instrument—How Constructed—Capacities of Station Meters—Cowan's Station Meter—The large Meter at the London Company's Works.

The station meter is an instrument employed at all well-regulated gas-works, to record the quantity of gas produced; and is as essential to the strict economy of an establishment, as the stock-book is to the merchant. This differs from the consumer's meter—hereafter to be described—in some minor points, but is in principle the same. The difference mainly consists in the exterior form. Station meters of small dimensions are cylindrical, whilst the larger descriptions are generally made square, and often very ornamental. The pipes for the entrance and exit of the gas are at the back. The dial of the index is in the centre in front, the float of the consumer's meter is dispensed with, and a glass gauge indicates the level of water; in other respects the station meter is identical in its action and construction with the consumer's wet meter.

The station meter is one of the most important objects of interest for a stranger in a gas-works, and is generally fixed in a locality especially arranged for it; and, whether of large or small dimensions, it is usually kept well painted, clean, and in good order. This apparatus is represented in the annexed engraving, Fig. 41, and consists of a cast-iron cylinder, containing the wheel and other parts, placed on a pedestal of brickwork, which gives it an ornamental appearance, also brings the index to the line of vision.

The capacity of a station meter required for a works is dependent on the maximum production of gas. When constructing this apparatus the general calculation is that the speed of the wheel shall not exceed 120 revolutions per hour. Therefore, adopting this basis, and supposing the maximum make of a works to be 7,200 feet per hour, or say 173,000 feet per diem, then the wheel would be required of such dimensions as to deliver 60 feet at each revolution. The principal defects arising from any increased velocity beyond that stipulated, consists in the extra friction or pressure necessary to work the meter; also, as ordinarily made, by the increased pressure, the water becomes depressed in the measuring chambers of the wheel, and consequently their capacity is augmented, and the meter registers "slow," that is, indicates less gas than has actually passed.

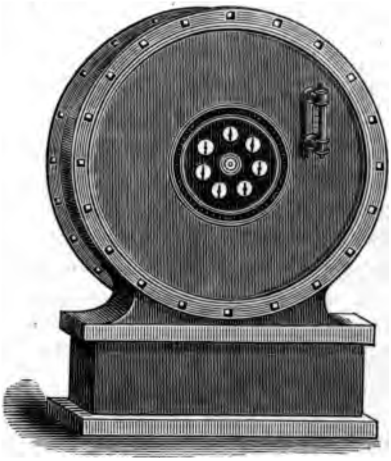


Fig. 41.

The following is a list of the maximum production in feet per hour, the capacity of each revolution of the wheel, and the prices of station meters in cast-iron cylindrical cases:—

Maximum hourly Production.	Capacity of each Revolution of the Wheel.	Prices of Meter, including Stamping Fee.
Cubic Feet.	Cubic Feet.	£
1,200	10	38
1,500	12½	45
1,800	15	51
2,400	20	56
3,000	25	62
3,600	30	75
4,800	40	94
7,200	60	140

Precautions to be observed in the station meter are, to maintain the water level always at the height indicated by the water-gauge. The meter should be level from back to front, as also along the line indicating the water level. A small stream of water should be continually flowing into and from it, in order to carry off any ammonia that may be deposited in the instrument.

In the smallest of works the index ought to be taken at least four times in the 24 hours, and in works of twenty million feet per annum and upwards, it should be taken every hour; and in all cases the account should be entered daily in a book kept for that purpose.

Accidents by the stoppage of station meters, either by breakage, or wear and tear, seldom occur; but in the event of this happening, and the passage of the gas being impeded at this point—in the absence of by-pass valves—all that is required to be done is to let a quantity of water run off from the meter, when the gas will have a free passage.

The index of a station meter, according to its capacity, contains five, or six, or more dials; the hands of which register in succession from hundreds, up to tens or hundreds of millions of cubic feet. In large meters attached to the index is a clock, the hour hand of which is connected with a rod carrying a pencil actuated by a slight spring. Immediately under the clock dial, and in the centre of the index, is a disc, which revolves about once in twenty-four hours, according to the daily production of gas. On this disc is fixed another disc, of paper, having divisions on its outer circle, corresponding with the maximum daily make intended to be indicated. The pencil mentioned receives its motion from the hour hand, and by the action of the disc revolving, makes a curved mark on the paper; so indicating the number of hundreds or thousands of feet of gas produced per hour. An inspection of the paper so marked shows at a glance any irregularity that may have occurred in the production of gas, affording the superintendent a good check on the workmen during his absence.

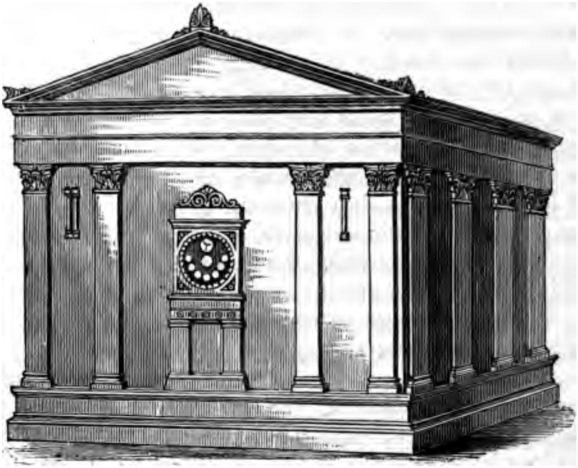


Fig. 42.

This apparatus is termed the "tell-tale," and although usually adopted in large meters, it is often indispensable in small works, where at times there is a rivalry between the men, and in which one party lays claim to a greater production than the other. By this apparatus such disputes are avoided.

Station meters, when intended to measure 100,000 feet per hour or upwards, are made rectangular, and generally of excellent architectural design. That represented in Fig. 42 is manufactured by Messrs. W. and B. Cowan, of Edinburgh, which for appearance we believe is not surpassed by any other firm.

The largest station meter in existence is erected at the London Gas Company's Works, Nine Elms, made to deliver 250,000 per hour, or, according to the old system of calculating, 6,000,000 cubic feet per diem. If, however, the modern way of estimating be adopted, allowing 120 revolutions of the wheel per hour, then it would be capable of delivering 7,000,000 cubic feet daily. The diameter of the wheel is 16 feet 6 inches, its depth 19 feet. The case is 19 feet 8 inches wide, 22 feet 6 inches deep, and 18 feet 6 inches high from the ground. The connections are 36 inches in diameter, and the total cost of the meter erected was £1,825. To give some idea of the size of this meter, it is of about the same dimensions as a small double-fronted cottage of one story high; and is as large as some retort-houses supplying 5,000,000 feet of gas per annum.

An important office of the station meter, when the quantity of coal carbonized is accurately known, is that by it any irregularity in the production of gas, either by low heats or escapes, is demonstrated.

CHAPTER XIII.

THE PHOTOMETER.

How Constructed—The Mode of Testing Gas—Different Kinds of Photometers—The Rule for Making a Photometer—Lowe's Jet Photometer—Tables to correct the Volume of Gas under different Temperatures and Atmospheric Pressures.

THE illuminating power of gas as generally defined by Acts of Parliament, is that when consumed in an argand burner at the rate of five feet per hour, the gas shall give the light of a certain number of sperm candles called "Standard candles," each consuming 120 grains of sperm, per hour. The number of candles varies from twelve to sixteen, according to the Acts controlling the operations of the respective companies supplying the larger portion of the towns of England; whilst in Scotland and some of the towns of the North where gas is produced from cannel coal, its average illuminating power is required to be of twenty-two candles, or as technically termed "twenty-two candle gas."

At one time the method employed to compare any two lights, was by observing the intensity of the shadows of an object as produced by the lights under examination; but the system which has been universally adopted in England for many years is by means of Bunsen's disc. To illustrate familiarly the action of this disc, if we take a sheet of writing-paper on which a small spot of oil or grease is placed, when the paper is held between the observer and the light, the spot will be transparent; but when held in the opposite position it will be dark. Now if the paper be placed in an apartment at right angles to the window in a vertical direction, at a point where the light on both its sides is exactly of the same intensity, the spot then disappears. Here we may remark that the light directly opposite a window of an apartment appears over a considerable space of the same uniformity; yet such is the sensitiveness of the simple appliance in question, that it is a matter of some little difficulty to ascertain the exact point, where the light is of that equality to cause the spot to disappear. This is the principle of the Bunsen disc as applied to the photometer, as now universally adopted for determining the illuminating power of coal gas; and teaches us what we may learn by simply observing the effect of light on a piece of greased paper.

The photometer disc, which acts identically like the oiled paper already mentioned, is formed of white bibulous paper of about 4½ inches in diameter, and in its centre is a round spot of about 1½ inch in diameter left in its ordinary condition, whilst the surrounding part is saturated with melted spermaceti. As thus prepared, when seen by a light, situated on the same side as the observer, the centre part will be light, and the outer ring dark, as shown at *A*, Fig. 43, which represents the disc enclosed within its frame removed from the screen, and supported by the saddle-piece on the photometer bar *F*. In this case the disc is seen by reflected light, that is, light reflected upon it; but if, now, the disc be placed between the observer and the light, the outer ring becomes transparent, consequently the light is transmitted through it. Hence these opposite effects are produced either by reflected or transmitted light; but in placing the disc in such a position that neither the one nor the other predominates, that is, when the light on both sides is exactly of the same intensity, the centre spot then disappears, and both surfaces of the disc assume the same white appearance throughout; and on this simple contrivance is based the construction of the photometer.

With this beautifully simple and effective appliance, it can be readily understood that if an argand burner consuming five feet per hour, be situated a given distance at one side of the disc, and a number of lighted candles placed at the same distance from its other side, that according to the number of candles required to produce a light of the same intensity as the gas, so will be the defined quality of the gas. Thus by these means, and weighing the candles both before and after an operation, the illuminating power of any kind of gas can be readily determined.

There are, however, some practical difficulties attending the operation as described, of which the most important are the number of candles required to be lighted, and the difficulty of placing them all in their exact positions at the moment of performing the experiment. To obviate this in practice, only one or two candles are used, and when making the scale of the photometer, advantage is taken of the well-known law, which defines that the intensity of light varies inversely as the square of the distance, that any object illuminated, is placed from the source of illumination, which is illustrated by the following table:—

	Square of distance.	Amount of light thrown on disc.
The disc distant from burner 1 foot	1	1
" " 2 feet	4	$\frac{1}{4}$
" " 3 "	9	$\frac{1}{9}$
" " 4 "	16	$\frac{1}{16}$
" " 5 "	25	$\frac{1}{25}$

Figure 43, page 228, represents a set of photometrical apparatus complete. F is the photometer bar, divided by a scale which accords with the position of the disc, corresponding to the various number of candles. A is the screen containing the disc; B, the experimental meter; C, the micrometer regulating tap and pressure-gauge attached to the gas-burner; D, the regulator to control the pressure of the gas under examination; E, scales for weighing the candles; I, a clock striking each minute; G, a box containing

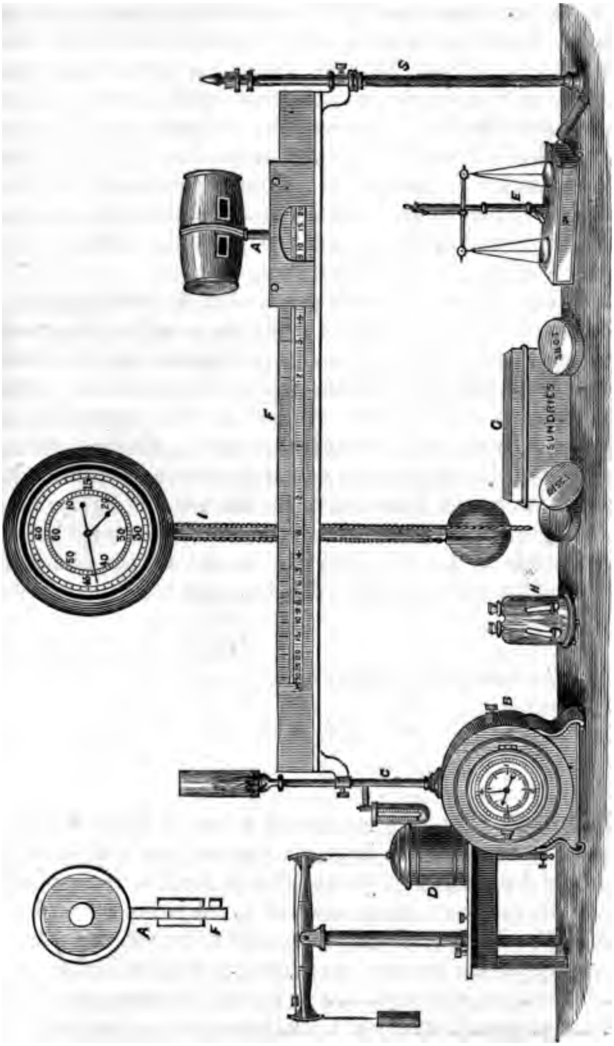


Fig. 43.

sundries; H, a "constant test;" and S is the standard carrying the candle; the whole being ready for operation.

There are various kinds of photometers, all of which, however, possess the various parts mentioned. The difference consisting, in one description having the candle movable instead of the disc, which apparatus has the advantage of a short bar. In another kind, black square wooden screens are employed, having orifices in their centre through which the rays of light pass. One of these screens intervenes between the gas light and disc, another is placed between the candle and disc; whilst two other screens are placed at the extreme ends of the photometer. The object of these screens is to prevent any reflection of light on to the disc. A description of photometer designed by Mr. Evans can be employed anywhere, even in daylight, without consideration as to the colour of the walls of the apartment. This is in reality a photometer enclosed within a wooden chamber, coloured black on the interior, and which excludes all daylight. In the centre of the front of the chamber are two sight holes, through which the reflection of the discs may be observed. When required, the operator is enclosed by a curtain, when any photometrical observation can be made with the same accuracy as in a completely darkened room.

Some engineers employ two candles instead of one, by which greater regularity of the light is obtained. When this is done the standard candle is cut in two pieces; these are placed side by side, and the thick and thin end are consumed together. Of course under these conditions only half of the indicated degree of light on the bar is taken.

With the ordinary photometer the locality where the observations are made should be arranged expressly for the purpose. The walls should be blackened, or hung with black unglazed cloth, all the windows and doors closed in such a manner as to exclude the daylight, and other precautions observed in order to avoid any reflection of light acting on the disc. The apartment should be at a moderate temperature, and with some apparatus, as those unprovided with a screen for the disc, no other person than the operator should be near the photometer; for the reflection from any white material will sometimes influence the results, and as the eye is easily deceived by the different colours emitted by the gas and candles, to ensure accuracy the utmost precision is necessary.

The operation of testing gas is one that demands great care; the gas should be burnt as near as possible at the rate of five feet per hour; for if it be much below this, the test will be unfavourably conducted for the gas, and if above, in most cases it will be in favour of the gas. Moreover, it is highly desirable to obtain good sperm candles, to have a proper burner, that commonly used being the Sugg No. 1, with a chimney 6 inches long and 2 inches wide for 16 candle gas, and burning as near as possible the quantity per hour stipulated. According to the instructions of the Metropolitan Gas Referees, "Each testing shall include ten observations of the photometer made at intervals of one minute;" however, in practice, three or four observations are made, each of which is noted, the average being taken as the result. On the termination of the experiment the candle is weighed, and reduced according to the time it is burnt, to the standard of 120 grains per hour. When candles consume much beyond that quantity per hour, it is prejudicial to the test so far as regards the quality of the gas, as when burning a quantity above the 120 grains per hour, the candles yield an increased degree of light for the quantity of sperm consumed.

When operating with the photometer, the candle is first weighed, and the time of lighting noted. The gas and candle are then lighted for some minutes previous to commencing the experiment. The quantity of gas is carefully adjusted to the required degree, say, to consume five feet per hour, which consumption once arranged is maintained by the regulator. The disc being already placed in its screen, the operator looks through the two orifices in front of the latter, and observes the colour or shade of the disc. He then moves the screen and disc in the direction necessary to obtain an equal degree of light on both sides of the disc and cause it to be uniform, or nearly so throughout in colour, and with little or no trace of the white spot in the centre or the dark ring around it. This accomplished, he observes the number of candles indicated on the bar by the pointer attached to the screen.

According to the instructions of the Metropolitan Gas Referees, in addition to testing the illuminating power of the gas, its volume at the time of operating should be corrected, to bring it to the temperature of 60° Fah. and 30 inches atmospheric pressure, (as indicated by the barometer,) which is the standard; and for this purpose tables are given on pages 237, 238, and 239.

In these instructions it is stated, "The gas examiner shall observe the temperature of the gas as shown by the thermometers attached to the meters, also the atmospheric pressure as indicated by the barometer.

"Suppose the barometer stands at 30 inches, and the thermometer at 48°; multiply the quantity of gas consumed by the *Tabular Number* corresponding to the indicatures of the barometer and thermometer, as given in the table, page 237, when the product will be the corrected volume of the gas, *i.e.* the volume the gas would have occupied at the standard temperature and pressure; thus:

Volume of gas consumed	5 feet
Tabular number of barometer and thermometer	1·025

Then 1·025 × 5 = 5·125, the corrected volume.

"The same object may be attained by simply dividing the illuminating power by the tabular number; thus the former being 15·334 candles, divided by 1·025, the correction for temperature and pressure, gives 14·9 candles as the corrected illuminating power."

The tables will also be found convenient for correcting the quantity of gas made, as indicated by the station meter; the quantity, being multiplied by the tabular number due to the temperature and pressure, will give the amount as if the gas had been at 60° Fahrenheit and 30 inches barometer.

Thus 2,000 feet of gas at 28·5 inches barometer, and 40° temperature, required its standard volume? Then 2,000 × ·989 (the corresponding tabular number) = 1,978 feet. Or the same quantity at 31 inches and 50° temperature. Then 2,000 × 1·054 = 2,108 feet (the standard volume).

In another chapter of this work the influences which control the volume of gas are referred to.

For managers who may be unprovided with a photometer, who are limited in their means, and who may be disposed to make that instrument, the following information, and distances on the scale up to thirty-six candles is given; the fractional parts may be ascertained with tolerable accuracy by subdividing the space between any two numbers.

For this object, the longer kind of photometer may be formed by a wooden bar, properly planed, of about 3½ inches wide, ¾ inch thick, and exactly 100 inches long from the centre of the burner to the centre of the candle. The scale is in front, and the point exactly in the centre of the bar, that is 50 inches from the centre of the gas burner, and candle, the figure 1 is marked; the reason for this being that as the standard of comparison is a candle, and the distances of the gas and candle from this point are equal, it follows that when the disc is at that point, and the light from the gas and candle is alike in intensity, the gas must be equal to *one* candle. According to the law of the squares of the distances already mentioned, in order to indicate that the gas gives the light of two candles, when only one candle is employed in the experiment, at 41·42 inches from the centre of the candle will be marked 2. Thus if the gas give the light of two candles, one only being in use, on the disc being placed at the point 2, the spot of the disc will disappear. All the various distances on the scale are marked in a similar manner according to the following table:

No. of Candles.	Distance of Division from Centre of Candle. Inches.	No. of Candles.	Distance of Division from Centre of Candle. Inches.
2	41·42	17	19·52
3	36·61	18	19·08
4	33·34	19	18·67
5	30·90	20	18·26
6	28·99	21	17·91
7	27·43	22	17·57
8	26·12	23	17·25
9	25·00	24	16·95
10	24·02	25	16·67
11	23·16	26	16·40
12	22·40	27	16·14
13	21·71	28	15·90
14	21·09	29	15·64
15	20·52	30	15·41
16	20·00	36	14·28

In photometers, as now generally made, the disc with its frame and screen is fixed to the saddle piece at right angles to the bar; at the back of the disc are placed two mirrors, cut from the same piece of glass in order to avoid any difference of colour, and fixed at right angles to each other. By these means the operator can compare both sides of the disc at the same time, instead of being obliged, as formerly, to carry in his memory the shade of one side when comparing the other. This system is now applied to all descriptions of photometers.

The two mirrors are enclosed within an oblong box having two small orifices in front (instead of the screen A) which can be made by any tinman, and it should be painted a dull black in order to avoid reflection. The saddle piece which carries the box or the screen, *n*, is about 8 inches long, lined on the interior with green baize or cloth, in order to prevent friction, and is so made, as to glide freely on the bar; care being taken that the pointer of the saddle piece is placed directly opposite the disc.

The discs can be readily purchased, and are better suited for the purpose than any that can be prepared in the ordinary way. In the absence of an experimental meter, an ordinary 3-light meter having a wheel of the capacity of one-eighth of a foot may be arranged for the object, which is done by dispensing with the square frame, altering the spout, and making the shaft to protrude through a stuffing box. A dial of seven or eight inches in diameter may be made in card-board, and its circumference divided and subdivided into 7·5 feet, on which the hand will indicate the hourly rate of consumption by an observation of one minute. This is readily explained, for as the hour is sixty times greater than the time of the observation, and the exact quantity delivered by the meter at each revolution being ·125 foot, the result is, that this multiplied by 60 gives 7·5 feet.

However, when there exist resources to purchase apparatus made by regular manufacturers, it is always advisable to do this in preference to making them.

DIMENSIONS OF TEST ARGAND BURNER AS DECIDED BY THE METROPOLITAN GAS REFEREES.

Number of holes	24	
Diameter of holes	0·045	inch.
Internal diameter of steatite top	0·480	„
External	0·840	„
Height from the upper surface of the gallery on which the glass stands, to the upper surface of the steatite top	0·75	„
Cone, internal diameter at top	1·08	„
„ „ bottom	1·50	„
„ height of, externally	7·75	„

Chimney for 16 candle gas, 6 inches internal diameter by $1\frac{7}{8}$ inch high.

Chimney for 14 candle gas, 6 inches internal diameter by $1\frac{6}{8}$ inch high.

LOWE'S JET PHOTOMETER.

A very useful little apparatus which is very generally in use in gas-works, in order to observe the quality of the gas continually as it is produced, is Lowe's Jet Photometer.

The jet photometer is based on the fact, that the length of a gas jet issuing from an orifice of a certain size, under exactly uniform pressure, varies according to the illuminating power of the gas, and the richer the gas, the longer will be the flame. This instrument is represented in one of its forms in Fig. 44, and consists of a steatite single jet fixed up on a very delicate pressure gauge governor, capable of indicating the hundredth part of an inch of pressure, which regulates the pressure of the gas. The burning jet is enclosed in a chimney having a scale of inches and parts engraved on it, and the height of the flame as shown by the chimney, indicates the quality of the gas. In some works the instrument in question is enclosed within a small cupboard, provided with suitable means for carrying off the products of combustion, having a glass door in front, on which is marked the scale of inches and parts; and immediately behind the jet is fixed a corresponding scale in porcelain, the lines of which are exactly level with the scale on the glass door, so that when making the observation, the lines of the two scales are observed. In this case the glass chimney is dispensed with.

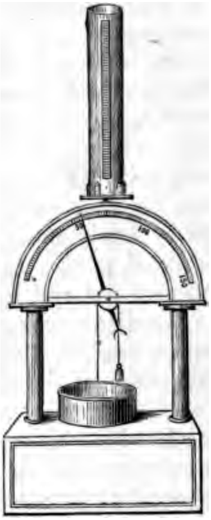


Fig. 44.

The jet photometer is very generally applied in works of large or medium capacity, where the gas is required to be delivered at any particular standard, for which it is accordingly arranged; hence the jet for this being we will suppose 6 inches in length, any augmentation or diminution of this will show an increased or diminished quality of gas.

Usually, one of these instruments is fixed in the engineer's office, burning the gas as produced, and indicates at once any error, whether arising from excessive exhaustion, neglecting to blow off the air from the purifiers, or other circumstances which would prejudice the quality of the gas.

Since the preceding was in type we have been favoured by Mr. John Methven with the description of a system that he proposes as a substitute for the photometer candle. This consists in replacing the candle by an argand burner, which is separated from the photometer by a black screen having a vertical oblong orifice of about 1½ inch by ⅜ inch immediately opposite the centre of the flame. Thus only a small portion of the light is permitted to pass to the photometer, and by experiment Mr. Methven has arrived at the dimensions of the orifice equivalent to two standard sperm candles. The approximative height of the flame is indicated on the chimney, but beyond this no other precautions are necessary. We witnessed some experiments made with common and cannel gas, and the results were precisely alike, the light emitted being in all cases exactly equivalent to two sperm candles. Should further experiments confirm those already made, photometry will be much simplified, and a more accurate standard established.

The following tables contain no correction for moisture, nor is this commonly considered necessary in practice, if the experiments are made in a dry room, at some distance from the gas-holder or vessel, in which the gas has been standing over water; and in applying them all the numbers of three figures must be regarded as decimals—thus the tabular number corresponding with 50° temperature and 29 inches barometrical pressure will be ·986.

TABLE TO FACILITATE THE CORRECTION OF THE VOLUME OF GAS AT DIFFERENT TEMPERATURES, AND UNDER DIFFERENT ATMOSPHERIC PRESSURES.

BAR.	THER. 32°	34°	36°	38°	40°	42°	44°	46°	48°	50°
28·0	988	984	980	976	971	968	964	960	956	952
28·1	991	987	983	979	975	971	967	963	959	955
28·2	995	991	987	983	979	975	971	967	963	959
28·3	998	994	990	986	982	978	974	970	966	962
28·4	1002	998	993	990	985	981	977	973	970	966
28·5	1005	1001	997	993	989	985	981	977	973	969
28·6	1009	1005	1000	996	992	988	984	980	976	972
28·7	1012	1008	1004	1000	996	992	988	984	980	976
28·8	1016	1012	1008	1003	999	995	991	987	983	979
28·9	1020	1015	1011	1007	1003	999	995	991	987	983
29·0	1023	1019	1015	1010	1006	1002	998	994	990	986
29·1	1027	1022	1018	1014	1010	1006	1002	998	993	989
29·2	1030	1026	1022	1017	1013	1009	1005	1001	997	993
29·3	1034	1029	1025	1021	1017	1012	1008	1004	1000	996
29·4	1037	1033	1029	1024	1020	1016	1012	1008	1004	1000
29·5	1041	1036	1032	1028	1024	1019	1015	1011	1007	1003
29·6	1044	1040	1036	1031	1027	1023	1019	1015	1010	1006
29·7	1048	1043	1039	1035	1031	1026	1022	1018	1014	1010
29·8	1051	1047	1043	1038	1034	1030	1026	1022	1017	1013
29·9	1055	1050	1046	1042	1038	1033	1029	1025	1021	1017
30·0	1058	1054	1050	1045	1041	1037	1033	1028	1025	1020
30·1	1062	1057	1053	1049	1044	1040	1036	1032	1028	1023
30·2	1065	1061	1057	1052	1048	1044	1039	1035	1031	1027
30·3	1069	1064	1060	1056	1051	1047	1043	1039	1034	1030
30·4	1072	1068	1064	1059	1055	1051	1046	1042	1038	1034
30·5	1076	1071	1067	1063	1058	1054	1050	1045	1041	1037
30·6	1079	1075	1071	1066	1062	1057	1053	1049	1045	1040
30·7	1083	1079	1074	1070	1065	1061	1057	1052	1048	1044
30·8	1087	1082	1078	1073	1069	1064	1060	1056	1051	1047
30·9	1090	1086	1081	1077	1072	1068	1063	1059	1055	1051
31·0	1094	1089	1085	1080	1076	1071	1067	1063	1058	1054

Table to Facilitate the Correction of the Volume of Gas at Different Temperatures, and under Different Atmospheric Pressures.

BAR.	THER. 52°	54°	56°	58°	60°	62°	64°	66°	68°	70°
28·0	948	944	941	937	933	930	926	922	919	915
28·1	952	948	944	940	937	933	929	926	922	919
28·2	955	951	947	944	940	936	933	929	925	922
28·3	958	955	951	947	943	940	936	932	929	925
28·4	962	958	954	950	947	943	939	936	932	928
28·5	965	961	958	954	950	946	943	939	935	932
28·6	969	965	961	957	953	950	946	942	939	935
28·7	972	968	964	960	957	953	949	945	942	938
28·8	975	971	968	964	960	956	952	949	945	941
28·9	979	975	971	967	963	960	956	952	948	944
29·0	982	978	974	970	967	963	959	955	952	948
29·1	985	982	978	974	970	966	962	959	955	951
29·2	989	985	981	977	973	969	966	962	958	954
29·3	992	988	984	981	977	973	969	965	961	957
29·4	996	992	988	984	980	976	972	969	965	961
29·5	999	995	991	987	983	979	976	972	968	964
29·6	1002	998	994	991	987	983	979	975	971	968
29·7	1006	1002	998	994	990	986	982	978	975	971
29·8	1009	1005	1001	997	993	989	986	982	978	974
29·9	1013	1009	1005	1001	997	993	989	985	981	978
30·0	1016	1012	1008	1004	1000	996	992	988	984	981
30·1	1019	1015	1011	1007	1003	999	995	992	988	984
30·2	1023	1019	1015	1011	1007	1003	999	995	991	987
30·3	1026	1022	1018	1014	1010	1006	1002	998	994	990
30·4	1029	1025	1021	1017	1013	1009	1005	1002	998	994
30·5	1033	1029	1025	1021	1017	1013	1009	1005	1001	997
30·6	1036	1032	1028	1024	1020	1016	1012	1008	1004	1000
30·7	1040	1036	1031	1027	1023	1019	1015	1011	1007	1004
30·8	1043	1039	1035	1031	1027	1023	1019	1015	1011	1007
30·9	1046	1043	1038	1034	1030	1026	1022	1018	1014	1010
31·0	1050	1046	1042	1037	1033	1029	1025	1021	1017	1013

Table to Facilitate the Correction of the Volume of Gas at Different Temperatures, and under Different Atmospheric Pressures.

BAR.	THER. 72°	74°	76°	78°	80°	82°	84°	86°	88°	90°
28·0	912	908	905	901	898	895	891	888	885	881
28·1	915	912	908	905	901	898	894	891	888	884
28·2	918	915	911	908	904	901	898	894	891	888
28·3	922	918	914	911	908	904	901	897	894	891
28·4	925	921	918	914	911	907	904	900	897	894
28·5	928	925	921	917	914	910	907	904	900	897
28·6	931	928	924	921	917	914	910	907	903	900
28·7	935	931	927	924	920	917	913	910	907	903
28·8	938	934	931	927	924	920	917	913	910	906
28·9	941	937	934	930	927	923	920	916	913	910
29·0	944	941	937	934	930	926	923	919	916	913
29·1	948	944	940	937	933	930	926	923	919	916
29·2	951	947	944	940	936	933	929	926	922	919
29·3	954	950	947	943	940	936	933	929	926	922
29·4	957	954	950	946	943	939	936	932	929	925
29·5	961	957	953	950	946	942	939	935	932	928
29·6	964	960	957	953	949	946	942	939	935	932
29·7	967	963	960	956	952	949	945	942	938	935
29·8	970	967	963	959	956	952	948	945	941	938
29·9	974	970	966	963	959	956	952	948	945	941
30·0	977	973	969	966	962	958	955	951	948	944
30·1	980	976	973	969	965	962	958	954	951	947
30·2	983	980	976	972	969	965	961	958	954	950
30·3	987	983	979	975	972	968	964	961	957	954
30·4	990	986	982	979	975	971	968	964	960	957
30·5	993	989	986	982	978	974	971	967	963	960
30·6	996	993	989	985	981	978	974	970	967	963
30·7	1000	996	992	988	985	981	977	973	970	966
30·8	1003	999	995	991	988	984	980	977	973	970
30·9	1006	1002	998	995	991	987	984	980	976	973
31·0	1009	1006	1002	998	994	990	987	983	979	976

CHAPTER XIV.

THE GOVERNOR, REGULATOR, PRESSURE GAUGE, AND PRESSURE REGISTER.

The Governor—Its Object—How Constructed—Wright's Governor—The Regulator—The Mercurial Regulator—The Dry Regulator—The Pressure Gauge—Crosley's Pressure Register—Wright's Pressure Register—Cowan's Automatic Pressure Changer.

THE governor is one of those ingenious self-acting machines which are equally admirable for their efficiency and simplicity. It is placed between the gas-holder and the main pipe, in order to regulate the pressure of gas supplied to the town or district, and controls any irregularity due to the unequal action of the gas-holders or to other causes; and, once adjusted, this instrument "governs" the pressure of the gas issuing therefrom during any indefinite period without demanding the least attention, and by it the pressure can be varied at will, according to the requirements, at different periods of the night.

This instrument is a gas-holder enclosed in its tank, provided with a peculiar valve which adjusts the pressure according to the weight placed on its holder. The tank is made of cast iron, the dimensions of which are dependent on the size of the mains for which it is intended and the space allotted for the apparatus.

Fig. 45 is a view of a governor, as frequently constructed for localities where space is limited or economy is desired, the tank and a part of the holder being in section, in order to show the interior: *a a* is a cylindrical tank, having the columns *b b* to support the bridge *e e*, in the centre of which is a guide for the flat rod *d*. The holder *g* is made of tinned iron, and is guided by rollers at its lowest edge, and the flat rod *d* above. It works very freely in the tank, and has a conical plug, *h*, suspended in it. The inlet pipe is exactly in the centre, and has a conical-seated flange at its top; the outlet pipe is concentric to it, and rises considerably above the level of the water,

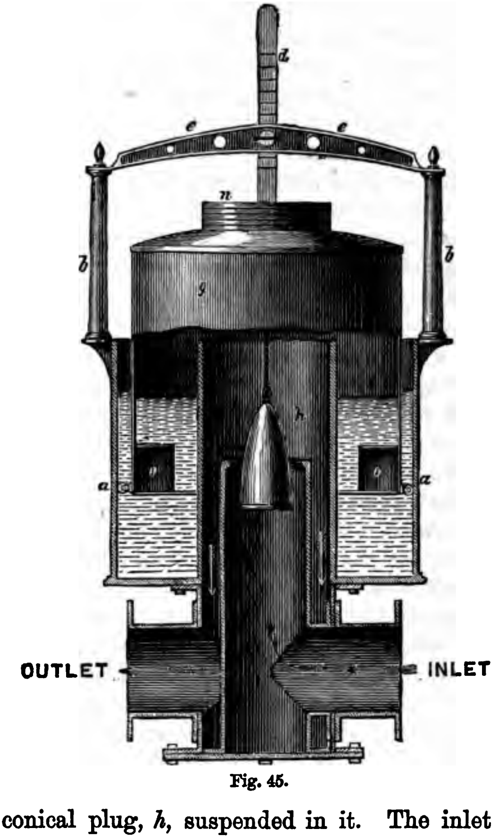


Fig. 45.

The holder is provided with an annular float, *o o*, of such buoyancy, that it rises when the tank is charged with the proper quantity of water, carrying with it the suspended conical plug *h*, the base of which is turned and fitted to the flange on the top of inlet, so as to be hermetically tight. The action of the instrument is very simple; for, on being supplied with water to the proper height, and supposing the whole of the weights *n* to be removed, the holder ascends, lifting with it the conical plug, which, on arriving at the top, stops the supply of gas; under which circumstances the governor is so adjusted as to give no pressure.

Now if a pressure of $\frac{8}{10}$ths, or any other degree, be requisite to supply a locality, then on placing equivalent weights on the holder, the necessary pressure is given; and no matter whatever variations may take place in the pressure in the works, or the quantity of gas consumed in the town, the same pressure is strictly maintained by the governor at its outlet. For should the quantity supplied be great, the holder descends with the plug, and so increases the size of orifice; and if the quantity passing be small, the holder rises, and the plug closes the aperture to the desired extent. Thus this simple machine delivers at all times any quantity of gas at the necessary pressure, according to the weights on the holder.

Sometimes these governors are made of considerably larger diameter than that shown when the outlet pipe is placed by the side of the inlet. The advantage claimed for this description is, that its holder contains a comparatively large quantity of gas, and that by the accidental shutting a valve on the works and immediately reopening it, the continuous supply would be maintained by the larger holder.

Another modification, called Wright's governor, is to substitute the float by a pillar, lever-beam, and counterbalance weights, the variation of pressure being produced by adding or abstracting the weights; in other respects this instrument is precisely like that already described.

In large works frequently the pressure is controlled by water flowing into or from a tank which is situated at the top of the holder. By this contrivance the loose weights are dispensed with, and the action of the governor when changing from one pressure to another is gradual and uniform, and is decidedly superior to the method of placing and removing the weights.

Another mode of governing the pressure of gas is by means of a diaphragm of leather affixed to the top of a cylindrical vessel having a conical plug and flange pipe similar to that already described, which will be described hereafter. These have been extensively used of late as district governors in hilly localities, and for this purpose they are buried in the ground.

When there are great variations of levels in towns, diaphragm or district governors are sometimes placed on the mains; when they are fixed on the principal main only, and the branch mains from one governor should be disconnected from those of another. Thus, if the highest level of a town be 200 feet, by placing a governor at an elevation of 50 feet, and another say 100 feet, and the third at 150 feet, and keeping the mains of the respective elevations separate from each other, in no part of the town will there be any excessive pressure; for supposing each governor to be adjusted to deliver $\frac{5}{10}$ths pressure, then in no case throughout the whole of the district will this exceed $\frac{10}{10}$ths. Whereas, in the absence of the instrument in question, if the pressure were $\frac{5}{10}$ths at the lowest point, it would be $\frac{25}{10}$ths at the highest, and thus necessarily offer great facilities for the escape and loss of gas. Lastly, another arrangement to attain the same end is by means of White's automatic valve, which is weighted so as to give the required pressure.

No gas-works should be without a governor; in some instances, where the pressure is left on the mains, it would repay its purchase money in a month by the saving effected from diminished leakages. In many works the foreman, or stoker, has continually to regulate the pressure during the hours of lighting by means of a valve, giving much trouble, and the work is done very imperfectly.

THE REGULATOR.

This instrument, like the governor already described, is for the purpose of regulating or controlling the pressure. There is, however, this difference between the two apparatus, that whilst the governor delivers the gas at the works during a portion of the night under variable pressures to meet the demands of the town; the regulator delivers it constantly at one uniform degree, regardless of any alteration of the pressure in the gas company's mains, so long as it is equal to that for which the regulator is adjusted. These instruments are used by consumers in order to adjust the pressure to the point most favourable for the consumption of gas, and obtaining the best light therefrom.

A description of consumer's regulator is identical in action with the governor mentioned at page 241, and is made with a tin or cast-iron case, and weighted so as to give the desired pressure essential for the economical consumption of gas wherever it may be employed. The pressure most suitable for ordinary uses for lighting and heating, is about $\frac{8}{10}$ths. When consuming gas for lighting an average of $\frac{6}{10}$ths will be sufficient, but when it is used for cooking, usually a greater pressure may be necessary, therefore for domestic purposes we have fixed the pressure stated.

A form of apparatus resembling that described is called the "mercurial regulator," in which the water is replaced by mercury. This apparatus possesses the advantage of avoiding the evaporation of the fluid employed in the instrument, and is used alike in dwellings, shops, public buildings, manufactories, and street lamps.

Another kind of regulator, known as the "dry regulator," is represented in its most primitive form in the accompanying figure. This consists of an outer case, A A, in which is hermetically fixed a very thin, pliable, and loose leather diaphragm, B; to the centre of the diaphragm, within the lower case D, is suspended the cone E, and the diaphragm is weighted at B to the pressure required to be delivered by the instrument. All this being arranged, the gas on entering the inlet pipe *h* elevates the diaphragm, which at the same time raises the cone and closes the aperture to the necessary degree to control the pressure; and whether there be one only or the full number of gas burners for which the instrument is made, their flames are constantly uniform.

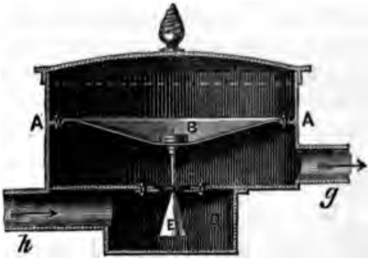


Fig. 46.

Whichever of the instruments may be employed, whether the water, mercurial, or dry regulator, in all there is but one object, that is to deliver the gas always at one uniform pressure, and by which considerable economy in its consumption is obtained. This is particularly the case in dwellings where the fishtail burner is very generally used with ordinary moon globes, by which great facilities are afforded for waste, as frequently they permit one-half of the gas to pass off without yielding any light whatever. It may, however, be observed, that supposing the pressure in the companies' mains always to be alike and moderate, there would be no necessity for the instrument in question; but in very few instances is this the case, the rule being that the pressure delivered by companies varies materially during the hours of general lighting, and in some districts this variation amounts to three or four inches during the evening.

Hence under general conditions for the economical consumption of gas, and in order to avoid the irregularities of burners, and particularly the argand, the regulator is indispensable, and it should be adopted alike in dwellings, shops, manufactories, and indeed in every place where economy is a consideration. This apparatus is usually placed on the service at the entrance to the premises, by the side of the meter. Its action is quite automatic, and once fixed, the mercurial and dry regulators require no attention whatever, even during a period of several years, and in many cases the saving effected by their use, repays their cost, in the course of two or three months; and it is to the interest of gas companies to encourage their employment.

We shall have occasion hereafter to refer to the lamp regulator, which is based on the same principles as those described.

THE PRESSURE GAUGE.

As already stated, when coal is distilled, the gas is expelled in a manner analogous to the production of steam from water. When gas is confined under ordinary pressure in a holder, it assumes a bulk about 250 times greater than that of the coal from which it emanated; and if not retained by these means, it would be divided or diffused to an indefinite extent, and lost. When gas is thus confined, the gas-holder may be so counterbalanced as to prevent it issuing, as under these circumstances, there being no weight, there would be no pressure; and by adding counterbalance weights, supposing an opening to exist, air would enter and intermix with the gas.

The pressure of gas in a works or any district, depends on a number of circumstances, such as the weight and area of the holders; the size of pipes through which the gas passes; the means of purification; the seal or dip of the hydraulic mains; and other obstacles which may be presented to its free passage; and it is essential to the strict economy of a gas establishment that the pressure existing in all the parts of the manufactory, as well as in the mains for distribution, should be known.

For this purpose a simple instrument called the "pressure gauge," as represented in the annexed figure, is employed. This consists of a glass tube about $\frac{3}{8}$ inch internal diameter, and 8 or 10 inches long, bent in the form of the letter U, with the graduated scale placed between the two tubes. The centre of the scale is marked zero, and the spaces above and below are subdivided into inches, and tenths of inches. The bent pipe is for the purpose of attaching the gauge to the fittings, and is screwed or tapped for that object.

When required for use, the gauge is filled with water to the line marked zero; it is then affixed to the pipe through which the gas is passing, when the pressure of the gas causes the water to be depressed in the tube *a*, and elevated in the other, *b*, the difference between the two water levels as read on the scale being the pressure of the gas. For example, if the water be depressed an inch below the point marked zero, and elevated the same distance above, the pressure will be $\frac{20}{10}$ths; or the scale may be dispensed with, and the difference of levels taken with an ordinary measure.

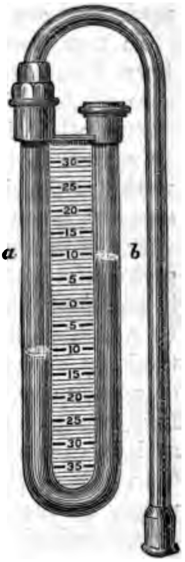


Fig. 47.

These gauges are often made with two straight tubes connected at the top and bottom by a small chamber. The advantages of this system are, that the tubes are easily taken apart and can be readily cleaned; they are also much stronger, as the bent tubes are very liable to break.

There are other means of indicating pressure by a closed cylindrical vessel which is divided into two distinct concentric cylindrical compartments, the water passing freely from the one to the other. In the central compartment is placed a float, with a rod attached to it, which is provided with a scale, passing through the cover of the vessel. The gas on entering the outer compartment depresses the water therein, consequently elevates it in the central compartment, by which means the float is raised, and the pressure indicated on the scale, by a pointer on the end of the rod, attached to the float. This principle is applied in various ways, sometimes with a dial in the centre, or with a pointer and semicircular scale. Instruments of this class are often made very ornamental.

In many establishments the maximum pressure in the town does not exceed 1 inch or 1½ inch, a minimum pressure of $\frac{8}{10}$ths being obtained in the lowest parts of the district, which is sufficient and ample for general purposes. In others, however, perhaps from the position of their works, or the size of mains, or the elevation of the locality supplied, much greater pressure is required.

For ordinary purposes, as when ascertaining the pressure in the mains of the town, a gauge 5 or 6 inches long is sufficient. The pressure in the streets may be known by attaching the gauge by means of a flexible tube to the lamp burners, or, if more convenient, on the premises of a consumer, but taking care that there is no supply from the same service. This operation should be adopted at least once a month in order to ascertain the pressure in the various districts; by these means in the event of stoppages, or the mains being too small, the defects will be ascertained, before they become annoying to the consumers.

At one period, when small mains and heavy pressure existed on works, pressure gauges were made with mercury instead of water, when they were of course of very limited size. However, the superior intelligence now engaged in gas manufacture renders these no longer desirable.

The gauges above described only indicate the pressure acting on them at a particular moment, and leave no record; but there are other instruments employed which not only indicate, but record rigidly, throughout the day and night, the pressure which has acted on them. Of these there are two kinds, and called pressure registers or indicators.

CROSLEY'S PRESSURE REGISTER OR INDICATOR.

This instrument in France is called *le mouchard*, the spy, signifying its duty to keep watch over and record the manner the workmen attend to their duty in the delivery of gas to the districts. Its action is automatic and continuous, requiring the application of a clock to indicate the various periods of time, whilst means are adopted to record the pressure.

This instrument was first manufactured by S. Crosley, and consists of a tank of cast-iron or tinned plate of about 3 feet deep and 16 inches diameter, in the centre of which is a vertical pipe in connection with the main. On the top of the tank is a receptacle for a vertical revolving cylinder of about 16 inches long and 5 inches diameter, enclosed by a glass frame secured with lock and key. The whole is surmounted by a clock which is connected to the cylinder and causes that to revolve once in twenty-four hours. Within the tank is a gas-holder of about 14 inches diameter and 16 inches high, having a float throughout its length to give it the required degree of buoyancy when immersed, but which gives a gradually increasing weight and consequently pressure on rising. The holder has proper rollers and guides to enable it to rise and descend in the tank with all freedom. Attached to the top of the holder is a rod which passes through the centre of the cover of the tank, and on the top of this rod, is a spring pencil for the purpose of recording the degrees of pressure.

Around the vertical cylinder is coiled a sheet of paper, which is marked into twenty-four vertical divisions to indicate the hours of day and night, corresponding with the clock above. There are also horizontal lines corresponding with the pressure, which are numbered, commencing from the bottom marked zero, continuing to forty or fifty tenths. Thus as the holder in rising, by reason of it having less buoyancy, acquires a greater degree of weight, it is obvious that this weight at various positions being ascertained, the scale of pressure can be arranged accordingly by the horizontal lines.

On the tank being supplied with water to the desired height, if there be no pressure the pencil will remain at zero; but if the gas be admitted, say at a pressure equal to 2 inches, the holder rises, and with it the pencil, which records the pressure on the horizontal lines of the coil of paper, while the vertical lines indicate the period that such pressure existed. By these means, during the whole of the day and night, the pressure is faithfully indicated and recorded by the pencil on the paper. In all well-regulated works the pressure indicator is employed, to which a fresh paper duly dated is supplied daily, and is afterwards kept as future reference in the event of any complaint arising.

Wright's Pressure Register.

The pressure register represented by Fig. 48 is a much smaller and cheaper instrument than the former, and was invented by the late A. Wright. Its size renders it very portable, its moderate price permits its being adopted in works of all descriptions, and it is largely used by gas companies to record the pressure existing in different parts of their districts.

This instrument consists of two concentric cylinders, the outer one, or case, *a a*, being about 16 inches diameter, closed at its base, also at the top over the annular space formed between the outer cylinder *a a* and the inner cylinder *c*. The annular and cylindrical chambers communicate with each other only through a small space left between the lower edge of the inner and the bottom of the outer cylinder. The case is surmounted by a clock enclosed in a glass shade. The clock, instead of having an ordinary face, is provided with a metal disc which carries a circular sheet of paper, divided by twenty-four radiating lines corresponding with the hours of day and night; also having a series of concentric rings corresponding with the various degrees of pressure. A float carrying a rod, D, and pencil similar to that of the pressure register, is placed within the inner cylinder, which is open at the top. When required for use, water is poured into the vessel *c* until it flows from the tap *e*. Gas being then admitted by the pipe *b*, the water is depressed in the annular chamber, and, elevated in the inner cylinder, and raising the float, causes the pencil to mark in accordance with the level of the

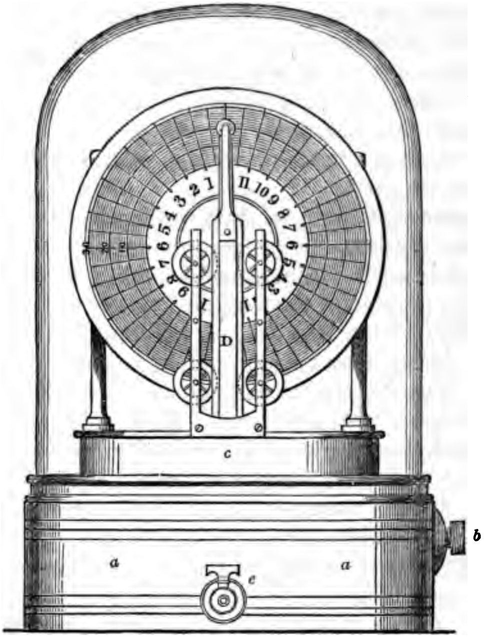


Fig. 48.

water in the cylinder *c*, and in agreement with the pressure acting thereon.

As already observed, fresh sheets or discs are required daily, and, as they may become very important records, should be carefully preserved. These instruments are very essential to the proper distribution of gas—they serve to correct irregularities, and point out the cause of complaint arising from any want of uniformity of pressure, and at the precise minute. The register enables the engineer or manager to adjust the pressure in the most delicate manner according to the requirements of the district during the successive periods of the twenty-four hours, when often a marked variation exists in the quantity of pressure required.

For instance, there are some works which throughout the day scarcely deliver a greater pressure than $\frac{3}{10}$ths of an inch, which is gradually increased, according to the demand for gas, the position of the town, and size of the mains, and in some instances, at the time of full lighting, a pressure of 4 or 5 inches may be required to be delivered at the works, although at remote parts of the district this may be reduced to a few tenths pressure. Again, as the lights are discontinued, the pressure is gradually reduced at the works until midnight, when it is further diminished to its minimum night pressure, until the hour when the street lamps are extinguished.

There is a modification of the pressure register, both Crosley's and Wright's, which records the action of the exhauster, and is very useful in order to prevent undue exhaustion, to which cause must undoubtedly be attributed the great variation existing at times, in the quality of gas supplied by companies; inasmuch, as shown elsewhere, as very slight quantity of air deteriorates the quality of gas in a marked manner.

A very ingenious contrivance for regulating the pressure to a town or district, called the Automatic Pressure Changer, has recently been invented by Mr. W. Cowan, of Edinburgh. By this machine the pressure can be controlled at various periods during the night and day for an entire week, according to the wants of the consumers and the public lighting; and once adjusted, by it the duty is performed with as much accuracy as with human supervision.

This is accomplished by a revolving disc, having the twenty-four hours marked thereon, corresponding with the hours of the clock which gives motion to the disc. There are also several tappets attached to the disc, at the points corresponding with the exact periods when the pressure has to be changed, and project a short distance beyond its periphery. There are two taps, one of which delivers water on to a governor and so gives the desired pressure; and by means of the other tap, the water is syphoned from the top of the governor when the pressure is required to be reduced. Each of these taps is actuated by its corresponding lever; thus in due course as the disc revolves according to the hour, one of the tappets comes in contact with a lever and opens its corresponding tap and allows a quantity of water to flow, which increasing the pressure to the required degree, acts on a small gas-holder forming part of the apparatus which rises and closes the tap. The reduction of the pressure is obtained in a similar way, by syphoning the water from the top of the governor, and the small gas-holder closes the tap when the degree of pressure is attained. Thus, as its inventor says:—"The functions of the instrument are—to open a tap for the supply of water to load the governor to any required pressure; to close the tap when such pressure is reached; and to repeat the same operations for the attainment of still higher pressures at such times, and to such degrees, as may be necessary. In like manner to open another tap for the withdrawal of water to unload the governor when a lower pressure is desired; to close the tap when such pressure is reached; and to repeat the same operations for the still further reduction of the pressure as often and to such extent as required."

We have heard that one of these apparatus worked in a highly satisfactory manner for a considerable period at a Metropolitan works, and no doubt there is a good future for the Automatic Pressure Changer.

We were only made acquainted with the apparatus in question after this work had been written and our space was fully occupied, otherwise we should have had great pleasure in presenting a drawing of this highly ingenious apparatus, which, however, would have entailed a much more comprehensive description than that given, and occupied considerable space.

The gas regulator has been one of the most favourite subjects for patentees, for which at least upwards of two hundred patents have been obtained without presenting any marked difference from those we have described; and at the present time hardly a month passes without an addition to the lists, continually repeating that which was accomplished many years ago.

CHAPTER XV.

APPLICATIONS AND MANUFACTURE OF RESIDUAL PRODUCTS.

Coke—Manufacture of Sulphate of Ammonia—How to ascertain the Value of Ammoniacal Liquor—The Hydrometer—Table of Specific Gravities, and Weight of Ammoniacal Liquor—The Alkalimeter—Apparatus employed—The Mode of Manufacturing—The Profits derived from the Process—Precaution to be Observed—Tar, Applications of, for Various Purposes—Breeze—Foul Lime—Foul Oxide of Iron—Methods of Preparing Test Papers.

COKE.

THIS residual is largely used for domestic purposes, for which it is often broken in pieces of about the size of a small orange, or rather less, which enables it to burn with great facility in ordinary stoves, and for that object the smaller the stove the smaller will the coke be required. There are two or three kinds of machines manufactured for breaking the coke.

Coke is also employed for steam boilers, and we have known it to be used abroad for locomotives. It is extensively used for burning lime; in short, it is employed for innumerable manufacturing purposes, and wherever a large quantity of caloric is requisite, generally it can be obtained at a cheaper rate from gas coke than from coal.

THE MANUFACTURE OF THE SULPHATE OF AMMONIA.

Of all the various compounds of ammonia, the sulphate is the most easily manufactured; it has always a ready sale; is not a perishable commodity in the ordinary sense of the term; requires no skill in producing it; and this compound should always represent an important item in the balance-sheet of every company making twenty million feet of gas per annum, and should yield, no matter where the works may be situated so long as the freight or carriage is reasonable, on the average about two shillings for every ton of coals carbonized; and the importance of the subject in question, by which tens of thousands of pounds may be saved annually to gas companies, particularly to those situated abroad, induces us to devote considerable space to it, in order that the process may be learned by any one so disposed.

The methods usually employed for determining the value of ammoniacal liquor are simple, and may be performed either by ascertaining its specific gravity or by neutralising it by means of an acid. For the first purpose all that is required is a hydrometer, or, as more expressively called in French, *pèse-liqueur*, or liquor weigher. Of these there are various kinds suitable for the different liquids they are intended, but that which is required for our purpose is called "Twaddle's hydrometer," No. 1, and is usually supplied with a glass jar, both of which may be had of A. Wright & Co., Millbank Street, Westminster, for six or seven shillings; of whom also may be procured the acids and other appliances hereafter mentioned. The apparatus in question is represented in the annexed Fig. 49, and consists of a glass jar nearly filled with the ammoniacal liquor about to be examined. In this liquor is the hydrometer, composed of a glass bulb *b*, to which is attached the lower bulb *c*, and the glass stem A. The lower bulb *c* contains a small quantity of mercury for the twofold purpose of adjusting the instrument and keeping its stem always in a perpendicular position. Within the stem is a scale, the top of which is marked 0, the numbers corresponding with the various degrees, increasing as they descend. When required for use the jar is placed on a stand and nearly filled with the liquor to be examined; the hydrometer is then gently placed in the fluid, and when it is perfectly steady the figure on the scale level with the surface of the liquid indicates the strength; thus if we suppose this figure to be 3, the ammoniacal liquor will be of the strength of 3 degrees Twaddle.

In the estimation of the liquor, however, it is usually defined by the "ounce strength," a term to be hereafter explained, and by a fortunate circumstance the "ounce strength," the weight per gallon in pounds, the specific gravity, and the degree of strength according to the Twaddle hydrometer, correspond with each other as represented in the table on the following page.

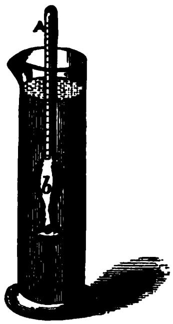


Fig. 49.

From this table we learn that a cubic foot of water weighs 1,000 ounces, hence that number denotes its specific gravity, and is universally adopted in chemistry as a standard of comparison for all other liquids. We also find that liquor of 3° Twaddle is equal to "6 ounce strength;" that one cubic foot of it weighs 1,015 oz.; therefore it follows that in each cubic foot of liquor of that strength there are 15 oz. of ammonia in combination with 1,000 oz. of water. Or if we suppose the liquor to be 10°, or 20 ounce strength, then each foot would contain 50 oz. of ammonia combined with 1,000 oz. of water.

Before proceeding further, it may be necessary to describe the means of ascertaining the presence of an acid or alkali in any liquid. For this object litmus test papers of about two inches long and half an inch wide are usually employed; these may be either purchased or prepared by the operator, for which instructions are given on page 175. Acids have the property of changing blue litmus paper to a reddish colour, when it is called "red litmus paper." Alkalis, on the other hand, change red litmus to its natural blue

TABLE SHOWING THE DEGREE ACCORDING TO TWADDLE, THE SPECIFIC GRAVITY, AND WEIGHT PER CUBIC FOOT, AND GALLON, WITH THE "OUNCE STRENGTH" OF AMMONIACAL LIQUOR.

Degrees Twaddle.	Sp. Gr. and Weight per Cubic Foot in Ounces Avoirdupois.	Weight per Gallon. lbs.	Ounce Strength.
Water.			
0	1000	10·	0
½	1002·5	10·025	1
1	1005	10·05	2
1½	1007·5	10·075	3
2	1010	10·1	4
2½	1012·5	10·125	5
3	1015	10·15	6
3½	1017·5	10·175	7
4	1020	10·2	8
4½	1022·5	10·225	9
5	1025	10·25	10
5½	1027·5	10·275	11
6	1030	10·3	12
6½	1032·5	10·325	13
7	1035	10·35	14
7½	1037·5	10·375	15
8	1040	10·4	16
8½	1042·5	10·425	17
9	1045	10·45	18
9½	1047·5	10·475	19
10	1050	10·5	20
10½	1052·5	10·525	21
11	1055	10·55	22
11½	1057·5	10·575	23
12	1060	10·6	24
12½	1062·5	10·625	25
13	1065	10·65	26
13½	1067·5	10·675	27
14	1070	10·7	28
14½	1072·5	10·725	29
15	1075	10·75	30
15½	1077·5	10·775	31
16	1080	10·80	32
16½	1082·5	10·825	33
17	1085	10·85	34
17½	1087·5	10·875	35
18	1090	10·9	36
18½	1092·5	10·925	37
19	1095	10·95	38
19½	1097·5	10·975	39
20	1100	11·	40

colour. Thus if a liquid, say water, contains acid even to the extent of a drop of strong acid in a gallon, on dipping a blue litmus test therein its colour is at once changed to that of red litmus; ammonia, on the other hand, being an alkali, is detected by red litmus, which by the action of the ammonia is restored to its original blue colour.

The sulphate of ammonia is a compound of ammonia, which is termed the base, combined with sulphuric acid, and when the two exist in the exact proportions—that neither the acid nor ammonia predominate—the liquid is termed "neutralised." Hence on being able to ascertain the quantity of acid necessary to neutralise the ammonia, the value of the liquor, or quantity of ammonia contained therein, is determined. For this object, let us, for example, suppose a gallon of ammoniacal liquor about to be investigated, which is placed in a glass or earthenware basin, in order to avoid any action of the acid on the vessel. Then, on placing a reddened litmus test paper in the liquid, the former is immediately changed to its blue colour. But if we now take a graduated phial, say of the capacity to hold ten ounces, containing strong sulphuric acid, arrangements having been previously made to carry off the fumes, then by slowly adding the acid to the liquor, at the same time stirring with a glass rod, an effervescence will take place, and as this subsides the acid must be added with caution. The liquid is now tested at short intervals, but as by the disengagement of sulphuretted hydrogen the test papers are liable to change colour, for that reason several papers may be required. Thus if we suppose that of the 10 ounces of sulphuric acid, that 8 oz. be required to neutralise the ammonia contained in the gallon, this would be called 8 ounce liquor. Hence the term of "ounce liquor."

In practice, however, the operation is much simplified, and for which purpose an alkalimeter, represented in the engraving, Fig. 50, is necessary. This is a glass vessel provided with a base, and divided by the scale into sixteen equal parts, commencing from the point 0 and descending. For using the apparatus, a solution of acid called 10 per cent. acid, is required, which is prepared in the following manner: one pound of strong sulphuric acid of the specific gravity of 1845 is mixed with distilled water until the solution measures exactly one gallon, the specific gravity of which will be 1064·3. This is also called test acid.

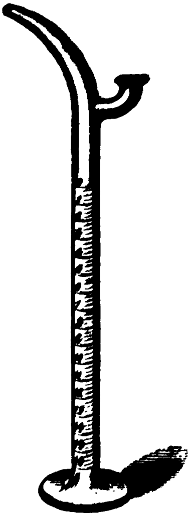


Fig. 50.

When operating, first fill the alkalimeter to the point marked 0 with the ammoniacal liquor about to be examined, which pour into a porcelain shallow basin; rinse the alkalimeter with a small quantity of water in order to prevent any loss of ammonia, this pour also into the basin containing the liquor. Now fill the alkalimeter to the point 0 with the test acid, which is then to be poured gently into the basin containing the liquor, at the same time stirring it with a glass rod. When the effervescence abates add the acid very cautiously, drop by drop, stirring the liquor and testing with the litmus paper at each addition of acid, until the test paper assumes a neutral grey or slightly red tint, when the neutralisation is effected. Then, on observing the quantity of test acid employed, the strength of the liquor is ascertained. Thus if we suppose that ten parts out of the sixteen have been used, the liquor examined will then be "10 ounce."

The operation of manufacturing the sulphate of ammonia consists in submitting the ammoniacal liquor to the action of heat, by which the ammonia is expelled, and then passes into a strong solution of sulphuric acid, which absorbs the ammonia; when, by the combination, crystals of the sulphate of ammonia are formed, which are removed and allowed to drain and dry. To further facilitate the liberation of the ammonia, lime is sometimes admitted into the boiler containing the liquor.

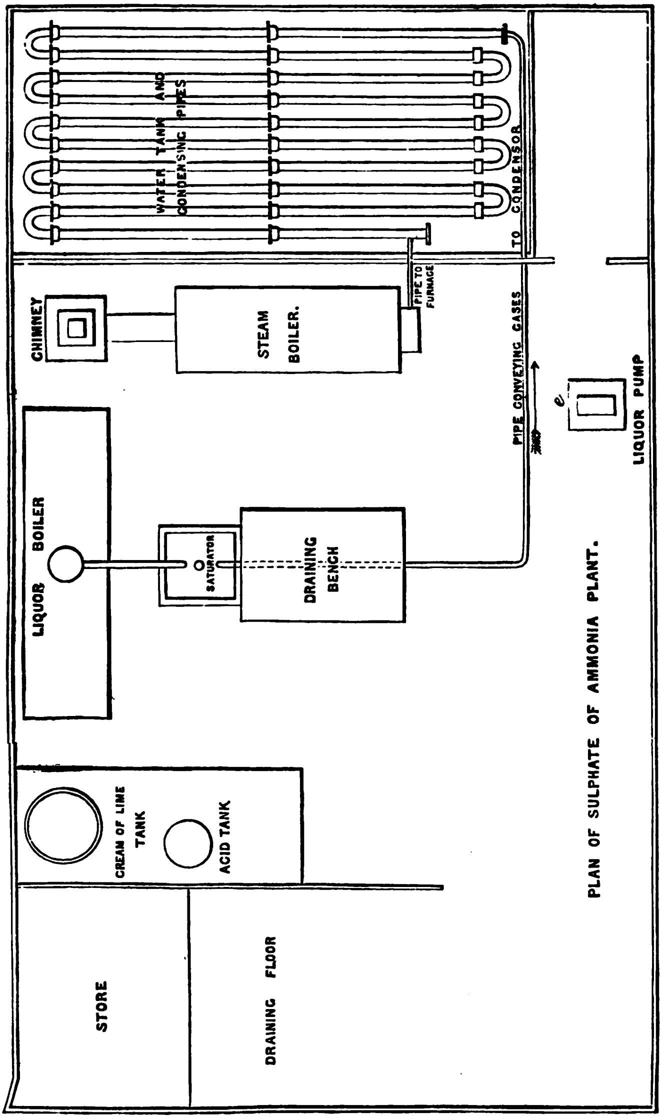
In the ordinary manner of manufacturing, the liquor is pumped into a large separating reservoir situated at a distance above the ground. After being allowed some time to repose, the ammoniacal liquor is conveyed to the boiler intended for its distillation, whilst the tar which settles at the bottom is run into its corresponding reservoir, or boiler.

During the many years that gas-lighting has been in existence, the process of manufacturing the compound under consideration has received less attention than, perhaps, any other matter connected with that art; and even at the present day, at works of considerable magnitude, the operation is conducted in the most slovenly manner, and sometimes the ammoniacal liquor is allowed to flow away to the sea, which is to be regretted on account of the value the product in question is daily assuming. We propose to describe the best apparatus that has hitherto come under our observation, as adopted by Mr. Browning, engineer of the Colchester Gas Company, which leaves nothing to be desired.

At those works for the manufacture of the sulphate there is a liquor tank, capable of containing 30,000 gallons, which quantity may in the course of time be allowed to accumulate, when the operation of manufacturing is commenced and continued for several days without interruption. Or the operation may be carried on at intervals more or less frequent as the liquor is produced.

At an isolated part of the works is a building erected expressly for the purpose under our consideration, as represented in plan in Fig. 51, page 262; but so far as regards the odour emitted in the process, the operation could be carried on in the midst of a populous neighbourhood without giving rise to any complaints of nuisance.

The apparatus for the operation consists of a steam



PLAN OF SULPHATE OF AMMONIA PLANT.

Fig. 51.

pump, *e*, of the cheapest and simplest description. A 10-horse steam boiler, having a communicating pipe in connection with the condenser and the furnace, for an object hereafter mentioned. Another cylindrical vessel, similar in shape to the boiler, but of larger dimensions and without a furnace, called the "liquor boiler," contains the ammoniacal liquor to be operated upon. From the dome of this vessel is a pipe which conveys the vapours and ammonia to the saturating vessel, or "saturator," and with the exception of this pipe, and that communicating with the steam boiler, the liquor boiler is hermetically closed.

The saturating vessel is placed on the ground, and composed of a wooden tank, *s s*, of about 5 feet square and 2 feet deep, lined throughout with lead, on the top of which is the gas chamber, as shown in plan and section above.

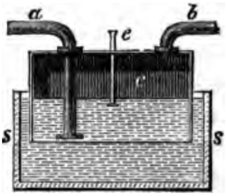


Fig. 52.

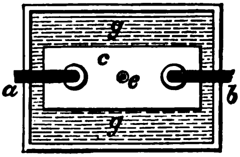


Fig. 53.

Fig. 52 represents a section of the saturating vessel and gas chamber, together with the corresponding pipes attached thereto. The saturator, represented by the letters *s s*, is simply a wooden tank lined with sheet-lead, and, as indicated by the dotted lines, it is filled with liquid. The gas chamber, represented by the letter *c*, consists of a leaden box closed at the top and open at the bottom, and dips a few inches into the liquid within the saturator. This chamber is supported by a wooden framing, which for simplicity of explanation is not shown. The pipe *a* comes direct from the dome of the liquor boiler, and passes to the bottom of the gas chamber, where it is made in the form of a horseshoe and perforated, or any other form that may be suitable for distributing the vapours of ammonia to the surrounding liquid. The pipe *b* carries off the gases resulting from the admixture of the ammonia with the acid, to the condenser, whilst the small pipe *e*, with the funnel at the top, delivers gradually the acid to the saturator as required. Fig. 53 is a plan of the same, all the letters of reference corresponding with the parts mentioned. As remarked, there is a space of about eighteen inches wide on each side of the saturator, indicated by the letters *g g*, called the "pockets," and from these pockets the crystals of sulphate are withdrawn as they are formed.

A leaden-lined vessel, the "acid tank," is the reservoir for the sulphuric acid, and from this, a pipe conveys the acid to the top of the gas chamber, where there is a regulating tap for adjusting the quantity.

A wooden bench lined with lead, the "draining bench," is fixed immediately adjoining the saturating vessel, and on this bench the sulphate of ammonia is placed as it is withdrawn from the bottom of the saturating vessel; after which it is allowed to drain, but subsequently it is removed to the "draining floor" adjoining, which is formed of wooden boarding with interstices, backed with sheet lead, where it is allowed to remain until sufficiently dry for delivery.

A small tank for mixing the lime and producing the milk of lime, in communication with a liquor boiler, completes the apparatus.

The condenser shown in plan consists of a number of 6-inch pipes connected together by semicircular bends, placed in a horizontal position within an oblong brick tank containing water, similar to a description of apparatus used sometimes as a gas condenser, and of course is provided with the means for removing condensed liquor.

When commencing operations in a new works, supposing everything to be in order as described, the saturator is charged with sulphuric acid. The ammoniacal liquor either flows from a tank placed at a suitable elevation, or is pumped from the reservoirs into its corresponding boiler, until it is within about one-sixth of being full. Steam is then generated in the steam boiler to the desired pressure. This boiler is, however, provided with an injector for the purpose of supplying it with water whenever it may be desirable.

The steam in the steam boiler, has a pressure of about 40 lbs. on the inch, the object of which is to convey a high degree of caloric, then passes into the liquor in the boiler, which speedily reaches the temperature necessary to expel the ammonia.

As the ammoniacal gas is disengaged it passes from the liquor boiler down the pipe *a*, unites with the acid, where the gases and vapours evolved, pass by the pipe *b* to the condenser. Here the vapours are condensed, and the gases pass to the boiler furnace to be consumed. Fresh acid is supplied by the small pipe *e* in quantities corresponding with the amount of ammonia liberated from the liquor boiler.

At certain periods the workman by his experience knows that crystals of sulphate of ammonia are formed and deposited at the bottom of the saturator, which he "fishes out" with a wooden shovel, and after allowing a short time for the salt to drain he places it on the draining bench immediately adjoining, and fixed at a suitable height for the operation.

Whether the supply of acid, or the ammonia, is in excess is ascertained by the specific gravity of the liquor in the saturator. Should this be too low, the ammonia will be in excess of the acid, when the fact will be made evident by the odour of ammonia at the furnace door, or at a small hole made for the purpose. However, by carefully observing the specific gravity of the liquid, this is avoided.

When the supply of ammonia becomes sluggish, in consequence of the most volatile parts having been given off, a quantity of cream of lime is allowed to flow into the liquor boiler, which liberates the rest of the ammonia.

Towards the last part of the operation the vapour from the boiler may be tested with red litmus paper, and on the whole of the ammonia being driven off the steam is shut off from the liquor boiler; when a steam tap, placed for the purpose, is opened, previously to letting the spent liquor run off; but if this precaution be not observed, some injury may occur to the boiler by a vacuum being formed within, or some of the liquor of the saturator may be syphoned into it.

The liquor left in the saturator serves for any future operation.

The sulphate is afterwards taken to the draining floor, which is an ordinary flooring placed at a slight incline made of deal battens about 2 inches wide, and separated about a quarter of an inch from each other; and about 6 inches beneath this is a receptacle for receiving the liquid from the sulphate, where it acquires the degree of dryness necessary to render it saleable according to general conditions.

As observed, during the process, sulphuric acid is allowed to flow continually in a small stream into the saturator; but as the liquid in this is always of a temperature of about 200°, the steam is not condensed at this point, but passes with the gases to the condenser.

The gases produced by the combination of the sulphuric acid and the liquor, from which fatal accidents have sometimes occurred when imperfect apparatus are employed, are conveyed directly to the condenser, where the vapour of water is condensed from them. The noxious gases then pass by a pipe to the interior of the furnace of the boiler already mentioned, and are consumed without occasioning either odour or inconvenience. The whole of the process is so simple, so free from the chances of accident, and perfect, as to enable us to recommend it to any company or corporation desirous of manufacturing the compound in question.

By the process hitherto adopted by Mr. Browning, the contents of his liquor boiler is worked off in twelve hours, in which time he produces from 10 to 11 cwts. of sulphate. But having in view a more economical method of working, that gentleman intends to adopt two smaller charges, which he expects to work off in sixteen hours with the production of 15 cwts. of sulphate.

Among the advantages of the process are that the whole of the apparatus is hermetically sealed, and the operation as described is of extreme simplicity. These, together with the facilities for packing the material, which may be either in bags or barrels, as well as in the means of transport or shipment, and the opportunities afforded for its disposal, as there are merchants who purchase it in quantities as small as four tons. These circumstances, together with the facts that the sulphate is not a perishable commodity in the ordinary sense of the term, that during the last few years, although its production has considerably increased, its price has been also augmented, being at the time of writing this about £19 per ton: all clearly prove how important a question is the manufacture of the compound in question when combined with a gas-works.

According to Mr. Browning, the net profits derived from manufacturing the ammonia on their works after all expenses are paid, together with interest on capital employed, are upwards of £500 per annum, which is sufficient to pay more than one per cent. dividend to the shareholders. From this we gather that an important revenue can be obtained from this drug, which is frequently allowed to flow away as useless, producing at times numerous evils.

According to Mr. Whimster, engineer of the Perth Gas Commissioners, "from 18 lbs. to 22 lbs. of sulphate of ammonia are obtained from each ton of cannel coal carbonized in the manufacture of gas, the average produce being about 30 gallons of ammoniacal liquor of 4½° Twaddle arising from the condensed liquor, and that obtained in the purifying apparatus per ton of coal. Of this liquor 1 ton, or 200 gallons will yield, 1 cwt. of sulphate of ammonia, and will require nearly that weight of sulphuric acid at 144° Twaddle, the actual proportion being in ordinary working about 92 per cent. With good sulphuric acid, made from sulphur, not from pyrites, a good light grey commercial salt is produced, containing 97 per cent. of pure sulphate, or 25 per cent. of pure ammonia."

One ton of cannel yields on the average 20 lbs. of sulphate of ammonia. This, at the present price of £19 per ton, is equal to 40·7d., from which, if we adopt Mr. Whimster's figures, 9·7d. will have to be deducted as the cost of acid, fuel, and labour, when there remains 2s. 7d. net return from this source for every ton of coal carbonized. However, from this the interest on plant and wear and tear will have to be deducted, which will leave about 2s. 6d. as the net profit on every ton of cannel, derived from the manufacture of the compound in question. The yield of sulphate from caking coal is less than from cannel, averaging about 16 lbs. per ton.

With these statements before us, it is evident that a most serious loss is sustained by every company which does not profit by this residual. At the Colchester works the consumption of coal is about 6,000 tons per annum; and yet within our knowledge, there are gas-works abroad carbonizing four times that quantity, where the whole of the ammonia is lost. Thus, taking the operations of the Colchester company as a basis, in a works carbonizing 24,000 tons of coal, the revenue from the source in question would be no less than £2,000 per annum, and this for a drug that is often permitted to flow away. The loss arising from this extraordinary carelessness at the numerous gas-works in the world, must be hundreds of thousands of pounds sterling per annum. This, however, is not all, for as the sulphate is generally employed as a fertilising agent, it follows that by the absence of that agent, the soil produces much less than it otherwise would, by which the loss to the world at large is considerably augmented.

It, therefore, becomes the duty of every manager of works of any importance, every secretary, and director of a company, and even the shareholders, to prevent this waste; and to profit by the manufacture of the compound in question, for the transport and sale of which such extraordinary facilities exist.

The necessary instructions for preparing the test papers referred to, which are also useful for testing the purity of the gas manufactured, are given on page 175.

From the preceding dimensions, and the quantity of coal carbonized being given, we are of opinion that an apparatus may be estimated for a works of any magnitude. For instance, say for an establishment carbonizing 2,000 tons of coal per annum a 3-horse boiler would be necessary, the liquor boiler would be required of about double the capacity, and a condenser formed of 3-inch pipes would be ample.

A precaution to be observed in this process, however, is to be sure that the chimney has a proper draught in order to carry off and consume the noxious gases, as in one instance within our knowledge the engineer of a works narrowly escaped with his life by insensibly inhaling the poisonous compounds as they issued from the furnace door. With a proper draught there will be no cause for apprehension. In some works where there are facilities for conveying the noxious gases directly into the main shaft, the condensing pipes are dispensed with, and the cost of the apparatus is of necessity materially reduced. Besides these advantages there is the great consideration of the entire freedom from danger.

TAR.

The residual tar which accompanies the ammoniacal liquor is an important source of revenue for a gas company. The quality of this for the purpose of distillation and obtaining the light oils therefrom, depends on the temperature at which the coals have been carbonized; for when they are distilled at low heats a large quantity of naphtha and other volatile hydro-carbons are retained with the tar; for, as already stated, the greater portion of the volatile products at extremely low heats are separated in a liquid state. But as the heat of the retort is increased, so is the quantity and quality of the tar diminished in value for the distiller; and when retorts are worked at very high heats, the tar is poor in volatile constituents, for the obvious reason that they have entered into the composition of the increased yield of gas obtained at a high temperature.

In many localities tar has a ready sale for chemical uses, for preparing wood, or making footways, or painting walls, and other numerous purposes for which it is generally sold retail. The distillation of tar requires a special knowledge of the subject, besides, even under the best conditions, it is always attended with some degree of risk and danger, as is made evident by the temporary buildings we sometimes see applied to that object, and which are frequently destroyed by fire. If for no other reason, the chance of the tar igniting, as it often does in manufactories, its distillation should not be attempted in a gas-works unless under very exceptional circumstances.

Should the locality where the tar is produced be favourable for its transport to a manufacturer, it is by all means the best way to dispose of it, that is if a reasonable price can be obtained. But in the absence of a market for it, the tar may with advantage be consumed in the manner described for heating the retorts, and in a works having only six benches, or settings, the yield of tar will be sufficient to heat one of them.

There are districts where pavements or footways are constructed with ballast intermixed with tar, so arranged as to make a sound, impermeable, good footway of considerable durability. For this object the ground or path should be first supported on each side, either by a wall, kerbstone, or timber, in order to retain the material to be employed. This effected, the path is levelled at about 1½ inch below the intended surface. Ballast is then obtained, the largest of which will pass through a sieve with 1 inch openings, and this can either be saturated with tar some days before use, so as to allow the most volatile portions to evaporate, or the ballast may be coated with hot tar from which some of the most volatile parts have been evaporated. The tarred ballast is then laid a thickness of about 1½ inch and levelled. This done, a quantity of hot tar, which has been deprived of a portion of its naphtha, is laid over the whole of the surface, and immediately after some fine gravel is spread over the tar to the thickness of a quarter of an inch. The whole is then levelled by a heavy garden roller, when the tar intermixes with the gravel, forming an even and good footway. This system is extensively employed in the suburbs of London and various other places, and is a profitable manner of disposing of the residual in question.

Breeze.

This residual is generally disposed of to brick-makers, and realises on the average about three shillings per ton. It is employed in conjunction with tar for making footways similar to that already described, but for this object the greater portion of the volatile matter should be first expelled from the tar. Breeze is also sometimes intermixed with a limited portion of tar, and after the two are well incorporated, the mixture is placed in moulds and submitted to a heavy pressure, by which means, blocks of fuel are produced, which in many localities will find a ready sale. This many years ago was a common fuel among the poorer classes in Paris, and where tar and breeze have an indifferent market they can be employed in the manner indicated.

Mr. Anderson has invented a machine for the purpose in question which is capable of making some tons of fuel per diem, and has been practicably employed with a considerable degree of success, although the object of that gentleman is simply to use the compressed material as fuel for the furnaces. But it is obvious that if it be suitable for that purpose, it will be equally so for domestic and industrial uses, by merely exposing the blocks of fuel in an oven or retort for a short time at a moderate temperature, in order to expel the most volatile constituents of the tar, and render the fuel hard; which is, indeed, the method adopted on the Continent.

Foul Lime.

The foul dry lime is generally appreciated in agricultural districts, but the price it realises is merely nominal. It has been proposed at various times to revive it in order to render it again effective as a purifying agent; in some localities where lime is expensive this might be profitably done.

Foul Oxide of Iron.

This, under some circumstances, is a marketable commodity, but for which purpose it is required to contain 50 per cent. of sulphur. The price it produces is but small.

CHAPTER XVI.

DISTRIBUTION.

First Mains laid—Various Kinds of Mains—Table of Weight of Pipes—Lead Joints—Turned and Bored Joints—Table of the Cost of laying Pipes—Duration of Mains—Table of the Quantity of Gas delivered from Pipes of various Diameters—The Importance of a Good Map of the District supplied—Condensation—Loss by Leakage—Table of the Cost of Mains—Services.

MAINS AND SERVICES.

HAVING entered into the manufacture of gas and the various apparatus employed therein, we now come to its distribution, which includes a knowledge of the means of conveying the gas to the various parts of the district, town, or city; likewise the methods of conducting it into and through premises, together with the burners and other apparatus, such as heating and cooking stoves, employed in consuming gas.

The pipes which conduct gas through the different streets are called main pipes or mains; and those which convey it therefrom to the houses are termed services.

Probably the first mains systematically laid throughout a town or city were those of the New River Company, upwards of two hundred years ago, for the purpose of distributing water throughout London.

These were simply trunks of elm-trees left on the exterior in their rude state, the interior being bored out to the required size, which varied from 2 inches to 10 inches diameter. One end of this pipe was tapered like a spigot, from which, no doubt, that part of cast-iron pipes takes its name; the other end had a conical seat to receive the spigot, and they were joined together with white lead or cement, and "driven home" with a mallet.

This rude state of laying mains existed until the commencement of the present century, when the combined requirements of gas and water led to the production of cast-iron pipes; but when gas companies commenced their operations, such was their excessive cost, that £18 and £20 per ton was the ordinary price then paid for them. By successive improvements introduced into this branch of industry the price has gradually diminished, and at the present day mains are obtained for less than one-third of that cost.

At one period, when cast-iron mains were very expensive, several attempts were made to substitute them by pipes of other material. In a city in the western part of England an extensive trial was made to transmit gas through brick conduits. Earthenware pipes, similar to the drain pipes of the present day, were also used; and bottle-glass mains were proposed, but never carried into operation. Pipes of earthenware were used on an extensive scale in some of the towns of France, the joints of which were made with Roman cement, and the services attached by punching a hole in the main and inserting the end of the leaden service-pipe, which was secured with cement. It is almost needless to say that this system resulted in complete failure, and several gas companies were all but ruined by resorting to it.

Subsequently a description of main was introduced into France and the Continent called, after the inventor, the "Chameroy" pipe. These are constructed of tinned or leaded sheet iron; the pipes, of 2 or 3 inches diameter, being of the thickness of ordinary stout tin plate, but they are made thicker according to the increased diameter, and thus, a 24-inch pipe is made of about No. 16 gauge plate.

In making these pipes the sheet iron is turned round to form the pipe, when it is riveted and soldered; and on the respective ends is cast corresponding male and female screws, made of a composition of tin, lead, and antimony, which are firmly soldered to the tube. The pipe then has a coating of tar internally, and a layer of asphalte, intermixed with sand, of from ¼ inch to ½ inch thick, according to its dimensions, on the exterior; and when laid, they are screwed together with a hempen washer dipped in tallow, forming a very sound joint. Another method applied within the last few years has superseded the screws, and consists of two pieces, which unite together similar to a bayonet joint. Although apparently so very fragile, these pipes are of extraordinary durability, many of them having been interred upwards of thirty-five years without showing the slightest symptoms of decay; and undoubtedly the nature of the material of which they are composed prevents to a great extent the action known by chemists as "endosmose" and "exosmose," which action is considered to exist to a serious extent with cast-iron pipes, and to be detrimental to the quality of gas transmitted through them.

By a law of nature, all gases have a tendency to divide, separate, or diffuse themselves; thus the poisonous air of confined places, the vitiated atmosphere of large towns and cities, or gases that may be engendered prejudicial to animal life, are diffused, and fresh air takes their place. This law is so powerful that gas, when confined in pipes or gas-holders, traverses the metal, and atmospheric air enters to replace it; which action occurs with gas in mains, and is called *endosmose* and *exosmose*, derived from the Greek, signifying impulsion, or pressure from within and without. Of course, the more porous the substance confining the gas, the more powerful is this action; hence the necessity of having the metal forming the pipes as compact as possible.

It is also believed that when gas is in a state of repose, that is not flowing, or as sometimes termed, "dead gas," the action of endosmose is greatly increased.

Cast-iron pipes are universally employed in England, and their manufacture is at present brought to a great state of perfection. As ordinarily made, when under 3 inches diameter, they are 6 feet long and barely ⅜ inch thick; when under 12 inches and above 3 inches diameter, they are 9 feet long, varying from ⅜ to ½ inch thick; when 12 inches diameter, or larger, they are generally made 12 feet long, but rarely exceeding ⅝ inch in thickness.

These pipes have on one end a socket, sometimes called a "faucet," sufficiently large in diameter to allow the end of another pipe to enter very freely. These sockets vary in length from 2½ inches to 6 inches, according to the diameter of the main, the first being for 2-inch pipes, the latter for those 36 inches in diameter. The other end of the pipe is called the spigot, and has a small bead cast on it, which prevents the yarn passing into the pipe when the joint is being made. The quality of iron for pipes is of the utmost importance; very soft black iron contains a large proportion of carbon, and this, by long use in the conveyance of gas, becomes sometimes so soft that it can be cut with a knife with the greatest facility, like the crust of bread.

Previously to being laid, the pipes should be tested separately by means of hydraulic pressure of at least two atmospheres; at the same time, a few blows struck along those under examination with a hammer will detect any fault that may exist. Should there be any cracks or flaws, these will be perceived by the water oozing therefrom, when the pipe should be at once rejected. A sound pipe will easily be distinguished from a cracked one by the ringing noise it gives when struck smartly with a hammer.

The following is a table of the weights and lengths of *mains as usually* employed for gas, but as the pipes of different manufacturers vary in thickness, the weights must, therefore, be considered as approximative :—

Table of the Weights and Lengths of Cast-iron Mains.

Diameter of Pipe in Inches.	Weight per Pipe.			Weight per Yard.			Length of Pipes in Feet.
	cwts.	qrs.	lbs.	cwts.	qrs.	lbs.	
2	0	1	16	0	0	22	6
2½	0	2	0	0	1	0	6
3	0	3	18	0	1	6	9
4	1	1	13	0	1	23	9
5	1	3	8	0	2	12	9
6	2	1	15	0	3	5	9
8	3	0	24	1	0	8	9
10	4	2	6	1	2	2	9
12	7	2	8	1	3	16	12
14	8	1	20	2	0	12	12
15	11	0	0	2	3	0	12
16	12	1	8	3	0	9	12
18	15	0	0	3	3	0	12
20	18	0	0	4	2	0	12

During the infancy of gas-lighting cast-iron pipes were made with flanges and put together with bolts and cardboard washers, but, whether arising from the settlement of the ground or whatever cause, they were very susceptible to breakage, which caused them to be abandoned, and the lead joint became universally employed. Some years ago the turned and bored joint was introduced by the late Mr. King, of Liverpool, and although various methods of jointing pipes have been proposed from time to time, only these two systems, the leaded and the turned and bored joint, are generally adopted.

The lead joints afford greater facilities than the other for laying where there are curves or bends and short lengths, and, in addition, they possess a degree of elasticity which in some localities may be desirable.

When making this joint the spigot of the pipe about to be laid is placed into the socket of that already laid, when tarred gasket of spun yarn is driven into the socket by means of "caulking," for about half its length. Afterwards the remaining portion is filled with molten lead, which when cold is "set up" with a thick caulking-iron; by which means the ring of lead is wedged sufficiently tight to prevent the escape of gas. Sometimes, when more than ordinary care is adopted, the joint is afterwards smeared or painted over with a composition of hot pitch and tallow, which serves to stop any very minute leakages.

Care must be taken in the operation when making these joints not to have a superabundance of lead on the outer part of the joint, or as termed "too full a joint," for in this case it often happens that in "setting up"—particularly if the workman be inexperienced—the socket splits; and if he conceals the results of his awkwardness, probably a leakage of consideration may exist during many years. The same casualty is likely to happen if the joint is not full enough, when the socket is sometimes split by the tool being wedged in. Main laying requires men who are well accustomed to the work.

The lead is poured into the joint by means of a belt of plastic clay attached around the edge of the socket, just leaving sufficient space for the quantity of lead required, a "gate" being left at the top, into which the metal is poured. Another plan for pipes of large dimensions is to have a flat ring of about 1½ inch wide and ¼ inch thick, the internal part of which fits closely to the pipe. This ring is jointed like a pair of callipers, which it resembles, and the two ends are turned at right angles, with bolt-holes to secure them together. This replaces the belt of clay, and when fixed the interstices around it and the pipe are smeared over with clay when it is ready for pouring the lead. This system, for large mains, is much to be recommended, for making a good joint and for the facility with which it can be done.

The other description, the turned and bored jointed *pipes, although* somewhat higher in price in consequence of the labour in turning, as will be seen hereafter, are cheaper than those of lead when laid. When laying these all that is required is to clean the turned faces and smear them over with red mastic, when the pipes are connected and driven home either with a mallet, or by a pipe suspended to shear legs, or by means of a screw working against a stake driven into the ground. When laid in a straight line of considerable length these pipes make an excellent job; they are readily put together, and perfectly sound; but under some conditions, as when placed on a dead level or slightly deviating from that, they demand extra care in laying, as the position of the pipe as regards its level is controlled by the manner it is forced home—thus, if struck above the centre, the end of the pipe will have a tendency to rise, and if beneath, it will descend below the proper level.

In very large pipes of 4 or 5 feet diameter, the New River Company employed a few years ago another means of making joints. In this case a bead is cast on both ends of the pipe, there being no socket. There is a collar or belt of cast iron, about 7 inches wide, made in three or more segments, which are secured together by bolts and nuts. The interior of this belt assumes the shape of, and fits tolerably close on to, the beads of the two pipes to be jointed. Previously to the iron belt being placed, a band of felt, of about the same width as the belt, dipped in tallow, is laid around the pipes and over the beads, when the cast iron segments are placed and screwed up, making a good, sound, cheap, and somewhat flexible joint.

We, however, witnessed a similar plan to this employed for the mains of a gas company abroad with the very worst results. Besides this, it was more costly than either of the ordinary methods of laying mains.

The annexed table of the cost of laying mains is taken from Mr. Newbigging's Handbook for gas engineers:—

TABLE SHOWING THE AVERAGE COST PER YARD OF LAYING MAINS WITH TURNED AND BORED JOINTS, AND WITH LEAD JOINTS, INCLUDING THE TOTAL EXPENSES OF MATERIAL (THE PIPES EXCEPTED), EXCAVATING, REINSTATING, AND MAINTAINING THE GROUND FOR SIX MONTHS AFTERWARDS. AVERAGE DEPTH FROM THE SURFACE OF THE GROUND TO THE UPPER SIDE OF THE PIPE, 1 FOOT 9 INCHES.

Diameter in Inches.	2		2		3		4		5		6		8		9	
Description of Joint.	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead.
	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
In ordinary ballast	0 7	0 10	0 8	0 11	0 9	1 2	1 0	1 5	1 2	1 7	1 3	1 9	1 8	2 5	1 9	2 8
In roads macadamized with Welsh or limestone	0 9	1 0	0 10	1 1	0 11	1 4	1 2	1 7	1 4	1 9	1 5	1 11	1 10	2 7	1 11	2 10
In paved roads, ordinary	0 10	1 1	0 11	1 2	1 0	1 5	1 3	1 8	1 5	1 10	1 6	2 0	1 11	2 8	2 0	2 11
In footpaths made with ashes, sand, or gravel	0 5	0 8	0 6	0 9	0 7	1 0	0 8	1 1	1 0	1 5	1 1	1 7	1 6	2 3	1 7	2 6
In footpaths flagged	0 7	0 10	0 8	0 11	0 9	1 2	1 0	1 5	1 2	1 7	1 3	1 9	1 8	2 5	1 9	2 8
In footpaths asphalted	1 8	1 11	1 11	2 2	1 11	2 4	2 1	2 6	2 3	2 8	2 4	2 10	2 9	3 6	2 10	3 9

Diameter in Inches.	10		11		12		14		15		16		18		20	
Description of Joint.	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead.
	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
In ordinary ballast	2 0	3 0	2 2	3 4	2 4	3 8	2 9	4 5	3 0	4 11	3 6	5 6	4 1	6 0	5 0	7 9
In roads macadamized with Welsh or limestone	2 2	3 2	2 4	3 6	2 6	3 10	2 11	4 7	3 2	5 1	3 8	5 8	4 3	6 6	5 2	7 11
In paved roads, ordinary	2 3	3 3	2 5	3 7	2 7	3 11	3 0	4 8	3 3	5 2	3 9	5 9	4 4	6 7	5 3	8 0
In footpaths made with ashes, sand, or gravel	1 10	2 10	2 0	3 2	2 2	3 6	2 7	4 3	2 10	4 9	3 4	5 4	3 11	6 1	4 10	7 7
In footpaths flagged	2 0	3 0	2 2	3 4	2 4	3 8	2 9	4 5	3 0	4 11	3 6	5 6	4 1	6 4	5 0	7 9
In footpaths asphalted	3 1	4 1	3 3	4 5	3 5	4 9	3 10	5 6	4 1	6 0	4 7	6 7	5 2	7 5	6 1	8 10

An evil to be avoided in laying mains is the system of contracting at an unreasonably low price, which contract is sometimes afterwards sublet. Under such circumstances, it follows that instead of the joints containing their proper quantity of lead, often only one-third of that is employed, when, although the joints may be caulked so as to be rendered sound at the time, yet on the slightest settlement of the ground they will become defective, and a continual source of loss to the company.

Sound mains are the first essential for the prosperity of a gas company, and, although during many years the leakage of gas was estimated at 30 per cent. of the production, modern practice teaches us that with ordinary care this should not exceed 10 per cent., whilst by some companies it is reduced to as low as 5 per cent.

Whenever the loss from unaccounted-for gas is excessive, the cause should be sought without delay. In some cases this occurs through an excessive supply to the street lamps. This, at the present time, with the improvements introduced into lamp regulators, by which any definite quantity is delivered, within a trifling percentage should never be permitted. As already observed, no doubt a large portion of the loss arises from the holders "blowing;" or the loss may arise from the consumers tampering with the meters; or the meters may be so defective as to allow a large portion of the gas to pass unregistered, and which can only be ascertained by proving every meter in the district. Years ago one of the London companies allowed their meters to fall into such a state of decay that the dividends of the shareholders suffered very severely in consequence.

Again, the loss may arise from defective services, or a main or service may be very defective, allowing the gas to escape at some out-of-the-way locality, where the odour arising from the escaping gas is disregarded. If, after having investigated all these points and corrected the evils, the loss from unaccounted-for gas continues important, then the only remedy is to test the mains, when the whole length may be divided into separate districts, each of which may be tested by a meter.

For this purpose the main will have to be cut at three or four points, and an experimental or other meter with suitable connections introduced, when the amount of leakage will be ascertained in each district. This accomplished, the judgment of the engineer or manager, will direct him as to the best course to be adopted, whether to strip the whole line of main, or one portion only.

Our opinion is that the loss from mains, unless recently disturbed, or when badly laid, is unimportant, inasmuch as the corrosion which forms itself on the pipe and joints generally serves to prevent the gas escaping; and even decayed services, which, when removed from the ground are perforated with large holes, often show no signs of an escape until they are disturbed; and that old mains are not conducive to heavy leakage is made evident by the small amount of unaccounted-for gas of the Gas Light Company, which has the oldest mains in the kingdom in use.

There are, however, certain destructive agencies which materially affect the durability of mains; thus it is said that the worst of all ground in which pipes can be laid is "that containing ashes, cinders, and moisture; in these the pipes are speedily covered with marks throughout, similar to pock marks, some of which eventually penetrate the metal. This action is undoubtedly due to electrical agency, by each of the numerous particles of carbon being in contact with the iron, which, aided by the moisture, form little batteries, and produce the rapid decay." In sandy, saline ground a coat of oxide forms itself on the exterior, which materially diminishes the thickness of the iron of the pipe, but the metal does not alter in its nature. In made ground, cast-iron pipes become rotten and soft. Lastly, in clayey soil the iron is kept in an extraordinary state of preservation; and we have known pipes to be embedded in clay with a view to their preservation. Therefore the duration of mains depends entirely on the soil in which they are laid.

In laying mains, the first consideration is the maximum quantity of gas likely to be required for delivery per hour; which decided, then a point in the town where there will be a general divergence of the pipes must be ascertained. The distance between this point and the works being known, the size requisite for the leading main may be determined by referring to the very accurate table calculated by the late Mr. Barlow, of the quantity of gas delivered per hour under certain pressures, by various sized pipes, of different lengths, which was published some years ago in the "Journal of Gas Lighting," of which the following is an abridgment.

The table is calculated on the supposition that the pipes are on a level; if there should be a descent to the part to be supplied, they ought then to be somewhat larger; on the contrary, should there be an ascent, their dimensions may be diminished.

DISCHARGES OF GAS IN CUBIC FEET PER HOUR THROUGH PIPES OF VARIOUS DIAMETERS AND LENGTHS, AT DIFFERENT PRESSURES.

(*The specific gravity of gas estimated at* 400, *air being* 1000.)

DIAMETER OF PIPE ½ INCH.

Length in yards		10	20	30	50	100
Quantity delivered	with 0·1 inch pressure	37·7	26·7	21·7	16·8	11·9
	” 0·2 ”	53·4	37·7	30·6	23·8	16·8
	” 0·3 ”	65·2	46·3	37·7	29·1	20·7
	” 0·4 ”				33·7	23·8
	” 0·5 ”					26·7

DIAMETER OF PIPE ¾ INCH.

	Length in yards	10	20	30	50	100
Quantity delivered	with 0·1 inch pressure	104·3	73·8	60·0	46·6	32·9
	„ 0·2 „	147·5	104·3	84·9	65·8	46·6
	„ 0·3 „			104·3	80·9	57·0
	„ 0·4 „				93·2	65·8
	„ 0·5 „					73·8

DIAMETER OF PIPE 1 INCH.

	Length in yards	10	20	30	50	100
Quantity delivered	with 0·1 inch pressure	214	151	124	95	67
	„ 0·2 „	302	214	175	135	95
	„ 0·3 „			214	165	117
	„ 0·4 „				190	135
	„ 0·5 „					151

DIAMETER OF PIPE 1¼ INCH.

	Length in yards	25	50	75	100	200
Quantity delivered	with 0·1 inch pressure	236	167	137	118	84
	„ 0·2 „	333	236	192	167	118
	„ 0·3 „		289	236	205	144
	„ 0·4 „				236	167
	„ 0·5 „					187

DIAMETER OF PIPE 1½ INCH.

	Length in yards	25	50	75	100	200
Quantity delivered	with 0·1 inch pressure	374	264	215	187	132
	„ 0·2 „	528	374	304	264	187
	„ 0·3 „		458	374	322	229
	„ 0·4 „				374	264
	„ 0·5 „					295

DIAMETER OF PIPE 2 INCHES.

	Length in yards	50	75	100	150	200
Quantity delivered	with 0·1 inch pressure	540	441	381	311	270
	„ 0·2 „	763	623	540	441	381
	„ 0·3 „		763	665	540	468
	„ 0·4 „				623	540
	„ 0·5 „					

DIAMETER OF PIPE 2½ INCHES.

	Length in yards	50	75	100	150	300
Quantity delivered	with 0·1 inch pressure	943	770	667	545	335
	„ 0·2 „	1335	1090	943	770	545
	„ 0·3 „		1335	1172	943	667
	„ 0·4 „				1090	770
	„ 0·5 „					861

DIAMETER OF PIPE 3 INCHES.

	Length in yards	100	150	250	500	1000
Quantity delivered	with 0·1 inch pressure	1054	859	666	471	333
	„ 0·2 „	1440	1214	942	666	471
	„ 0·3 „		1487	1153	815	576
	„ 0·4 „			1332	942	666
	„ 0·5 „				1054	744

DIAMETER OF PIPE 4 INCHES.

	Length in yards	100	250	500	750	1250
Quantity delivered	with 0·1 inch pressure	2160	1366	966	788	611
	„ 0·2 „	3054	1932	1366	1114	864
	„ 0·3 „		2366	1673	1366	1058
	„ 0·4 „			1932	1576	1222
	„ 0·5 „				1761	1366

Diameter of Pipe 5 inches.

Length in yards		100	250	500	750	1000
Quantity delivered	with 0·1 inch pressure	3540	2245	1587	1296	1122
	„ 0·2 „	5005	3174	2245	1832	1587
	„ 0 3 „		3888	2748	2245	1943
	„ 0·4 „			3174	2592	2245
	„ 0·5 „				2888	2508

Diameter of Pipe 6 inches.

Length in yards		250	500	750	1000	1500
Quantity delivered	with 0·1 inch pressure	3770	2660	2170	1880	1530
	„ 0·2 „	5320	3770	3130	2660	2170
	„ 0·3 „	6520	4620	3770	3270	2660
	„ 0·4 „	7540	5320	4340	3770	3060
	„ 0·5 „		5970	4860	4210	3430

Diameter of Pipe 8 inches.

Length in yards		750	1000	1250	1500	1750
Quantity delivered	with 0·6 in. pressure	10940	9450	8480	7760	7150
	„ 0·8 „		10940	9780	8940	6260
	„ 1·0 „			10940	9900	9237
	„ 1·5 „				12200	11300

Diameter of Pipe 10 inches.

Length in yards		750	1000	1250	1500	1750
Quantity delivered	with 0·6 in. pressure	19120	16500	14800	13500	12500
	„ 0·8 „		19120	17050	15600	14400
	„ 1·0 „			19120	17400	16150
	„ 1·5 „				21300	19600

DIAMETER OF PIPE 12 INCHES.

Length in yards		750	1000	1250	1500	1750
Quantity delivered	with 0·6 in. pressure	30200	26100	23300	21400	19800
	„ 0·8 „		30200	26900	24600	22700
	„ 1·0 „			30200	27500	25450
	„ 1·5 „				33600	31250

DIAMETER OF PIPE 15 INCHES.

Length in yards		1250	1500	1750	2000
Quantity delivered	with 0·8 inch pressure	47000	42800	39800	37200
	„ 1·0 „	52600	48000	44400	41600
	„ 1·5 „		58700	54300	50800
	„ 2·0 „			62800	58700

DIAMETER OF PIPE 18 INCHES.

Length in yards		1500	2000	2500	3000
Quantity delivered	with 0·8 inch pressure	67600	58800	52300	33800
	„ 1·0 „	75700	65600	58800	53500
	„ 1·5 „		80000	71800	65600
	„ 2·0 „			82800	75700

DIAMETER OF PIPE 20 INCHES.

Length in yards		1500	2000	2500	3000
Quantity delivered	with 0·8 inch pressure	88000	76500	68400	62400
	„ 1·0 „	98800	85300	76500	69800
	„ 1·5 „		102300	93500	85300
	„ 2·0 „			108000	98800

DIAMETER OF PIPE 24 INCHES.

	Length in yards	1500	2000	2500	3000
Quantity delivered	with 0·8 inch pressure	137200	119000	106000	97000
	„ 1·0 „	155000	135600	119000	108600
	„ 1·5 „		163000	145500	135600
	„ 2·0 „			168000	155000

DIAMETER OF PIPE 28 INCHES.

	Length in yards	1500	2000	2500	3000
Quantity delivered	with 0·5 inch pressure	161000	140000	125000	114500
	„ 1·0 „	229000	198000	177000	161000
	„ 1·5 „	280000	241000	216000	198000
	„ 2·0 „		280000	250000	229000

DIAMETER OF PIPE 30 INCHES.

	Length in yards	1000	2000	3000	4000
Quantity delivered	with 0·5 inch pressure	234000	166000	135000	117000
	„ 1·0 „	332000	234000	192000	166000
	„ 1·5 „		287000	234000	203000
	„ 2·0 „			270000	234000

DIAMETER OF PIPE 36 INCHES.

	Length in yards	1000	2000	3000	4000
Quantity delivered	with 1·0 inch pressure	530000	372000	303000	265000
	„ 1·5 „		456000	372000	322000
	„ 2·0 „			428000	372000
	„ 2·5 „				416000

To apply these tables, let us suppose the maximum consumption necessary for a town to be 25,000 feet per hour; the length of main from the works to a general divergence of the mains 1,500 yards; and the maximum pressure one inch; then on reference we find a close approximation to the quantity, and that a 12-inch leading main would be necessary.

The principal leading main having been decided on, in a similar manner approximations must be made of the various quantities likely to be required per hour in each distinct locality, and providing the mains accordingly, taking into due consideration the probabilities of improvement, or increase, in the various districts.

It is of the utmost importance to have the main pipes sufficiently large; many companies have lost considerably by the escapes of gas caused by the high pressure indispensable with small mains; afterwards, when they were increased in size, the loss by escapes has been reduced materially, and the company's profits increased in like proportion. Another inconvenience of small mains, is the very irregular pressure of the gas during the hours of full lighting. The first leading mains that were laid to supply London with gas were 3 inches in diameter, now from the Beckton works to London they are 48 inches in diameter.

It is very important to have a good map, not only of the site of the works, but of the whole district to be supplied with gas; on this map the course of all mains should be laid down, and the position of all syphons marked.

In addition to a mere surface plan, a network of levels should be taken over the whole district, and the grades or inclinations of all the mains marked. The relative elevations of the whole district with reference to some fixed point near the gas-holder would be best shown by contour lines of equal heights drawn throughout the district. When the town is nearly all on the same level, contour lines may be laid down at intervals of 2 or 3 feet vertical height, but where the streets are very steep, intervals of 6 or 8 feet would be sufficient. The best rule for laying on the contours is, that they ought to be so frequent as to show by a mere inspection of the map the level of every part of the surface with reference to the fixed datum line.

The admirable surveys of towns made under the directions of the officers of the corps of Royal Engineers, and plotted on a scale of 5 feet to 1 inch, are exceedingly well adapted for the delineation of gas and water pipes.

There are abundant examples of the mistakes made by gas companies for want of proper maps of their mains. We heard some years ago of a main being laid to supply a street, when by accident it was discovered that two other pipes were already laid, although no one knew of their existence. It has been asserted by a writer on this subject that in a street of half a mile in length not less than twelve syphons have been discovered on taking up the main, while one, or at most two, would have been sufficient to drain the main. Blunders of this kind are evidently occasioned by the want of maps to refer to, showing the works already executed, and which would have prevented the repeated errors.

Generally the mains in small towns are laid in or near the centre of the road, but in large towns they are laid in the footway close to the houses, this plan being adopted in order to avoid the expense of long services, and for the general convenience of the public.

Gas in its passage from the works carries with it a quantity of vapour of water, which depends principally on the temperature of the water in the tanks of the gas-holders. The vapour existing from this cause, in its transit through the pipes underground is condensed, and if no provision were made the water would eventually obstruct the pipes and stop the passage of the gas; therefore water receivers (or *syphons*, as generally, although improperly, called) are placed at certain intervals to collect the condensed liquor, which syphons should be as few as possible, consistent with the perfect drainage of the mains, in order to avoid unnecessary expense in placing them; unnecessary labour in trying them; and the probability of some of them being neglected.

Of necessity the mains must always incline into these syphons, to enable the water to drain into them, which is afterwards pumped out when desirable.

Much has often been said of the large quantity of gas condensed in its transit through the mains; which is decidedly erroneous, for if the vast condensation existed which many pretend, it would be made apparent by the nature of the liquid deposited in the syphons. That this liquid arises from the condensation of vapours carried off with the gas, is made evident by the fact, that in summer, when the production of gas is at the minimum, the condensation in the syphons is at the maximum, arising from the heat of the holder and the gas therein, which causes a large quantity of vapour to pass off into the mains. Therefore, with every confidence, we may say that the loss from condensation in mains, in the ordinary way of manufacturing gas, is not appreciable; but when gases are so produced that the hydrogen does not chemically combine with the carbon, or when they are subjected to severe cold, then the deposit of carbon by condensation is often very considerable.

Leakage in mains is a continuous and serious source of loss to a company; for this reason gas mains should never be laid with undue haste; the operation requires the utmost care, for on this greatly depends the success of the enterprise.

An excellent plan to preserve pipes, and to prevent leakage to some extent, is to coat them when heated with pitch, or they should be painted inside and outside with thick tar, and no gas mains should be laid without this precaution.

The position of the works in relation to the locality to be supplied, together with the size of the leading mains, must determine the pressure at which the gas should be delivered; thus, a town and works being on the same level, if the mains are ample, the gas having a pressure of 1 inch to 1½ inch at the outlet of works should be sufficient for the supply of the whole district.

Some extraordinary instances have occurred where, either by error or necessity, the works have been situated at the highest part of the district; when this happens the pressure must be increased very considerably, in order to supply the lower districts. When the works are situated very low, sometimes the gas may issue at an exhaust of $\frac{3}{10}$ths or $\frac{5}{10}$ths of an inch, this being dependent on the position of the nearest light to be supplied.

When mains are obstructed either by the deposit of naphthaline, or by water accumulated in consequence of not having drainage; a portion, or perhaps the whole, of the district is often without a proper supply of gas, occasioning the manager much annoyance and trouble. The way to discover the point of the main so obstructed is of the greatest simplicity.

To detect where a stoppage exists in a main, recourse must be had to the pressure-gauge; with this the pressure should be taken on the line of main when in *full lighting*, at various intervals of say 100 or 200 yards, commencing from the works. This may be done on the public lamps or on the premises of a consumer; but it is imperative that no light be burned on the same service during the trial, as this would cause a variation from the true pressure on the main, caused by the friction of the meter, or the gas passing through the pipes.

Following the line of main, and noting the pressure at each point where tried, if the decrease be very gradual, this will be due to the friction of the gas in passing; and should the pressure further gradually decrease until insufficient for supplying the lights, then the main is too small for the quantity of gas delivered.

But should the decrease of pressure between one point *and another*, say in a distance of 100 yards, be sudden and excessive, say a difference of three or four tenths, then it may be concluded that an obstruction exists between these two places. This ascertained, perhaps it may be necessary to fix air-pipes, which are simply ½-inch or ¾-inch short pieces, screwed into the main, closed by a plug or cap, and placed at various points where the stoppage is suspected, with a block over them. During full lighting the pressure is again tested on the air-pipes, when the stoppage will be detected within a few yards. The remedy then is to cut the main, and remove the naphthaline, if that should be the cause; or should the stoppage arise from an accumulation of water, the main must either be relaid or a syphon placed.

Some curious stoppages have existed in gas mains; for several years a basket of tools remained in a pipe, and was only discovered by the impediment offered to the passage of the gas when the main was worked to its full power. On another occasion a wooden plug was found; and within our knowledge a pipe was obstructed by a quantity of coal, which arose from the pipes and coal forming the same cargo being stowed together, and at the time of placing it, the main layer neglected to see that the pipe was clear.

On the Continent, generally, there is a main-tap on the exterior of premises attached to the service supplying, for the purpose of shutting off the gas when desirable. These taps were also formerly used for turning on and off the supply daily to contract consumers: at sunset a workman of the company turned the gas on to each house, and again went his rounds at the various hours, according to the respective contracts, to shut it off. By these means such serious loss as was incurred at one time by gas companies in England, where the supply was kept on continuously, was prevented.

The following is an abstract from a more comprehensive table by Mr. Newbigging of the cost of mains, which will be found of great utility to all managers and engineers:—

TABLE GIVING THE COST PER YARD OF CAST-IRON MAIN PIPES, AT RATES FROM £5 TO £9 PER TON.

Cost per Ton.	Cost per Yard.									Diameter in Inches.				
	2	2½	3	4	5	6	8	10	12	14	15	16	18	20
£ s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
5 0 0	0 11¾	1 3	1 6¼	2 3¼	3 0½	3 11¾	5 4¼	7 7	9 5½	10 6½	13 9	15 5	18 9	22 6
5 2 6	1 0	1 3½	1 6¾	2 4	3 1¼	4 1	5 6	7 9¼	9 8½	10 9½	14 1½	15 9½	19 2¾	23 0¾
5 5 0	1 0½	1 3¾	1 7¼	2 4¾	3 2¼	4 2	5 7½	7 11½	9 11¼	11 0¾	14 5¼	16 2	19 8¼	23 7½
5 7 6	1 0¾	1 4¼	1 7½	2 5½	3 3¼	4 3¼	5 9	8 2	10 2	11 4	14 9½	16 7	20 2	24 2¼
5 10 0	1 1	1 4½	1 8	2 6	3 4	4 4½	5 10¾	8 4¼	10 5	11 7	15 1½	16 11	20 7½	24 9
5 12 6	1 1¼	1 5	1 8½	2 6¾	3 5	4 5½	6 0¼	8 6½	10 7¾	11 10¼	15 5¾	17 4	21 1¼	25 3¾
5 15 0	1 1½	1 5¼	1 9	2 7½	3 6	4 6¾	6 2	8 8¾	10 10½	12 1½	15 9¾	17 8½	21 6¾	25 10½
5 17 6	1 1¾	1 5¾	1 9½	2 8	3 6¾	4 8	6 3¼	8 11	11 1½	12 4½	16 2	18 1	22 0½	26 5¼
6 0 0	1 2¼	1 6	1 10	2 8¾	3 7¾	4 9¼	6 5¼	9 1¼	11 4¼	12 7¾	16 6	18 6	22 6	27 0
6 2 6	1 2½	1 6½	1 10¼	2 9½	3 8¾	4 10½	6 6¾	9 3½	11 7¼	12 11	16 10	18 10½	22 11¾	27 6¾
6 5 0	1 2¾	1 6¾	1 10¾	2 10¼	3 9½	4 11½	6 8¼	9 5¾	11 10	13 2	17 2½	19 3	23 5¼	28 1½
6 7 6	1 3	1 7¼	1 11¼	2 10¾	3 10½	5 0¾	6 10	9 8	12 0¾	13 5¼	17 6½	19 8	23 11	28 8¼
6 10 0	1 3¼	1 7½	1 11¾	2 11½	3 11½	5 2	6 11½	9 10½	12 3¾	13 8¼	17 10¼	20 0	24 4½	29 3
6 12 6	1 3½	1 8	2 0¼	3 0¼	4 0¼	5 3¼	7 1¼	10 0¾	12 6½	13 11½	18 2½	20 5	24 10¼	29 9¾
6 15 0	1 4	1 8¼	2 0½	3 1	4 1¼	5 4½	7 2¾	10 3	12 9¼	14 2¾	18 6¾	20 9½	25 3¾	30 4½
6 17 6	1 4¼	1 8¾	2 1	3 1½	4 2	5 5½	7 4½	10 5¼	13 0¼	14 5¾	18 11	21 2	25 9½	30 11¼
7 0 0	1 4½	1 9	2 1½	3 2¼	4 3	5 6¾	7 6	10 7½	13 3	14 9	19 3	21 7	26 3	31 6
7 2 6	1 4¾	1 9½	2 2	3 3	4 4	5 8	7 7½	10 9¾	13 5¾	15 0	19 7¼	21 11	26 8¾	32 0¾
7 5 0	1 5¼	1 9¾	2 2½	3 3½	4 4¾	5 9¼	7 9¼	11 0	13 8¾	15 3¼	19 11	22 4	27 2¼	32 7½
7 7 6	1 5½	1 10¼	2 3	3 4¼	4 5¾	5 10¼	7 10¾	11 2¼	13 11½	15 6½	20 3½	22 8½	27 8	33 2¼
7 10 0	1 5¾	1 10½	2 3¼	3 5	4 6¾	5 11½	8 0½	11 4½	14 2¼	15 9½	20 7½	23 1	28 1½	33 9
7 12 6	1 6	1 11	2 3¾	3 5¾	4 7½	6 0¾	8 2	11 6¾	14 5¼	16 0¾	21 0	23 6	28 7¼	34 3¾
7 15 0	1 6¼	1 11¼	2 4¼	3 6¼	4 8½	6 2	8 3¾	11 9¼	14 8	16 4	21 4	23 10½	29 0¾	34 10½
7 17 6	1 6½	1 11¾	2 4¾	3 7	4 9½	6 3	8 5¼	11 11½	14 11	16 7¼	21 8	24 3	29 6½	35 5¼
8 0 0	1 6¾	2 0	2 5¼	3 7¾	4 10¼	6 4¼	8 6¾	12 1¾	15 1¾	16 10¼	22 0	24 8	30 0	36 0
8 2 6	1 7¼	2 0½	2 5½	3 8½	4 11¼	6 5	8 8½	12 4	15 4½	17 1½	22 4	25 0	30 5¾	36 6¾
8 5 0	1 7½	2 0¾	2 6	3 9	5 0	6 6¾	8 10	12 6¼	15 7½	17 4½	22 8	25 5	30 11¼	37 1½
8 7 6	1 7¾	2 1¼	2 6½	3 9¾	5 1	6 7¾	8 11¾	12 8½	15 10¼	17 7¾	23 0	25 9½	31 5	37 8¼
8 10 0	1 8	2 1½	2 7	3 10½	5 2	6 9	9 1¼	12 10¾	16 1	17 11	23 4½	26 2	31 10½	38 3
8 12 6	1 8¼	2 2	2 7½	3 11¼	5 2¾	6 10¼	9 3	13 1	16 4	18 2	23 8½	26 7	32 4¼	38 9¾
8 15 0	1 8¾	2 2¼	2 8	3 11¾	5 3¾	6 11½	9 4½	13 3½	16 6¾	18 5¼	24 1	26 11½	32 9¾	39 4½
8 17 6	1 9	2 2¾	2 8¼	4 0½	5 4½	7 0¾	9 6	13 5¾	16 9¾	18 8½	24 5	27 4	33 3½	39 11¼
9 0 0	1 9¼	2 3	2 8¾	4 1¼	5 5½	7 1¾	9 7¾	13 8	17 0½	18 11½	24 9	27 9	33 9	40 6

All mains should be drilled, and not cut with the gouge, which, even in the best of hands, is but a very imperfect method. Apparatus are manufactured which permits of the operation being effected with the loss of only an inappreciable quantity of gas, which apparatus, under some conditions, as in confined localities, is absolutely indispensable; indeed, we think that it should always be applied when drilling a charged main, as the saving of gas effected would speedily pay the expense of purchasing the machine. The price of this drilling apparatus made by Cort and Son for three sizes of pipes, including drills and taps complete, is about £9, which admits of their employment in works of very limited capital.

SERVICES.

The services to the houses and lamps in the United Kingdom, as well as in many other places, are of wrought-iron pipe. But on the Continent lead services are extensively employed. A great advantage possessed by the former is its rigidity, remaining straight, without any undulations; but, on the other hand, in some soils, if the iron is not properly protected, it speedily decays, when in the event of its being subjected to the slightest disturbance a serious leakage of gas is the result. There are, however, various ways of preserving iron services, if gas companies would only take the trouble and incur the limited expense it entails. One of these systems is to prepare a rude angular trough formed by two pieces of board, each about two inches in width, and nailed together, which is placed immediately beneath and almost touches the service when laid; the trough is then filled with hot pitch and sand so as to cover the pipe, which effected, the iron may be said to be everlasting.

There are certain soils which are alike destructive to lead and iron, but they cannot possibly have any effect on pipes inclosed in pitch as described; that system can therefore be strongly recommended.

Another method consists in painting the pipes before laying them with hot pitch, which system, however, is not equal to that mentioned. There is reason to believe that Professor Barff's and Mr. George Bower's system for preserving iron will be extensively applied to wrought-iron pipes, when neither of these preventive measures will be necessary.

Here we may observe that the most important improvement made in modern times in connection with the manufacture of iron is that for its preservation against atmospherical influences, patented by the gentlemen just mentioned; and as Mr. Bower's system is the simplest we proceed to describe it. The iron to be operated upon is placed in a chamber or retort, which is kept at a temperature of about 1,200° Fah. The chamber being hermetically closed, a limited supply of air is allowed to enter, when the iron gradually absorbs its oxygen, and at the end of five or six hours it acquires a coat of black oxide, which arrests any further oxidation. The author has had a sample of iron so prepared exposed to every change of the weather during nearly two years, and on which there is not the slightest trace of oxidation in the ordinary sense of the term; thus proving beyond all doubt the preservative power of the process, and points to the desirability of its employment in all the various parts of a gas-works, as well as in the mains and services.

When lead services are employed they require to be supported by wooden battens during their whole length underground; or in the absence of this, on the loose soft ground settling, recesses will be formed, leaving places in the pipe for the water to collect, which may either impede the passage of the gas altogether, or cause very disagreeable oscillations of the lights.

But however well services may be laid, it frequently occurs that in the course of time they become obstructed by naphthaline, when in order to remove this the air-pump or service cleaner must be employed. This apparatus consists of an air-pump with a receiver, on which is a stop-cock, and is provided with two lugs at its base. When in operation the service cleaner is connected with the obstructed service by means of an india-rubber flexible pipe; the workman then stands on the two lugs, and by means of the pump compresses a quantity of air into the receiver, which effected, he suddenly opens the stop-cock, when by the force of the compressed air the obstruction is removed from the service.

Various opinions exist concerning the formation of that troublesome compound naphthaline, but our experience is that wherever 7 or 10 per cent. of cannel coal is used with caking coal, naphthaline is not found in the mains or services, nor under these conditions have we ever met with it in a works.

Sometimes galvanized iron pipes are used for services, which no doubt are admirably suited for work above ground, but in some soils the zinc is very rapidly destroyed, and for this reason they should not be used.

Services like the mains are required to be laid with a slight incline to the main, or, where the level of the ground prevents this, one or more bottle syphons, which are made of the capacity of one pint and upwards, with T piece for connecting to its corresponding service, should be placed.

The following list taken from Richards' Treatise gives the diameter of service pipes for supplying a given number of lights with a pressure of $\frac{5}{10}$ths in the main, each light consuming five feet per hour, together with the quantity of gas the service is capable of delivering per hour, supposing this to be open at the end.

	Lights.	Diameter. of Pipe.		Yards.	Quantity per Hour. Cubic Feet.
From	1 to 5	$\frac{3}{4}$	inch length of service in	.. 150	.. 60
„	5 „ 10	$\frac{3}{4}$	„	.. 100	.. 74
„	10 „ 20	1	„	.. 100	.. 151
„	20 „ 40	$1\frac{1}{4}$	„	.. 100	.. 264
„	40 „ 70	$1\frac{1}{4}$	„	.. 25	.. 528
„	70 „ 100	$1\frac{1}{2}$	„	.. 25	.. 890
„	100 „ 150	2	„	.. 100	.. 1033

CHAPTER XVII.

CONSUMERS' METERS.

The Meter first invented by Clegg—Malam's Improvements—Congreve's Meter—Wet Meter described—Various Improvements—Warner and Cowan's Meter—Contingencies of the Wet Meter—The Motive Power Meter—The Dry Meter—Contingencies of the Dry Meter.

At a very early period of gas-lighting, the meter became an object of great importance, both to the manufacturers and consumers of gas, in order to possess the means of determining the consumption, so that a proper adjustment of charges might be made. The system of charging the consumer an annual rent for a certain number of burners, on the supposition that they consumed a given quantity per hour, and were used daily for a certain number of hours, was found to be exceedingly vague and unsatisfactory. Besides it obviously afforded the means of much fraud, and gas companies were necessarily obliged to leave an ample margin to cover the contingencies of dishonest burning; thus the conscientious consumer was charged heavily to make up for the delinquencies of a large class who were less scrupulous.

The merit and honour of having invented and constructed the first gas-meter is due to the late Samuel Clegg, who in 1815 patented "a gauge or rotative gas-meter." This *instrument*, although very ingenious, was far from being a *practical machine*; it afterwards underwent various modifications, but never attained that degree of perfection essential for its general adoption.

In 1816 the firm of Clegg and Crosley was established to manufacture meters in accordance with the patent mentioned, but so imperfect was their action, that a regulator was attached in conjunction with each instrument to counteract the oscillation of the lights.

The following year the very ingenious John Malam invented another description of instrument for measuring gas, which undoubtedly led to the construction of the meter since so universally employed and so justly appreciated. However, Malam, from some unaccountable cause, never patented his invention, and as early as 1818 Clegg and Crosley abandoned their mode of constructing meters for that invented by the first-named gentleman. On the occasion of his meter being presented by Malam to the notice of the Society of Arts, Clegg asserted that it had been copied from him. This serious charge was investigated by a committee of the society, who ultimately, after great deliberation, gave their verdict in favour of Malam, by awarding him their gold medal for his "invention of a gas-meter, new, ingenious, superior to all others, and likely to be of great benefit to the public." The extraordinary originality of invention since displayed by Malam has confirmed the decision of the Society of Arts, whilst an admission has been made, in the Treatise on Coal Gas written by the son of Clegg, under the sanction of his father, that Malam introduced the "hollow cover," so removing all doubt on the matter.

Among the first instruments proposed for the indication of the quantity of gas passing, was that invented by Sir William Congreve; which consisted of a kind of timepiece attached to the main tap, so that, in the act of turning this on, a pendulum was set in motion, which marked on the dial the time the tap was open; and when the supply was shut off, the pendulum was stopped. By these means the number of hours the gas had been burning was ascertained in a tolerably accurate manner, but, of course, even an approximation to the quantity consumed could not be arrived at. However, it was far superior to the general system of contract, where the gas was left entirely at the mercy of the consumer.

These instruments, at one period, were much used in France, the accounts being made out according to the number of hours indicated by the instrument, multiplied by the number of lights on the premises, and were called *compteurs à l'heure,* or hour meters.

In Continental works during many years after the introduction of gas, a much greater surveillance was observed as regards the consumption of gas, than in the United Kingdom, where it was left continually on the premises of the consumers, which of course was subject to continual abuse and loss to the company; whereas on the Continent the gas was turned off from each house at the hour contracted for, and turned on again at sunset.

There are two kinds of gas-meters now in use, the "wet" and the "dry" meter. The former is so called because it requires a quantity of water, to render it effective; the latter derives its name from the absence of such liquid, it being complete in itself.

Each description of instrument has its advocates; for whilst some gas companies countenance only the wet, others will use but the dry meter. Whilst engineers greatly interested in gas companies prefer the one, there are others similarly situated who have directly the opposite opinion; therefore, with those different views, it cannot be expected that a definite opinion of their respective merits will be given here: nevertheless, the progress made by the dry meter during the last thirty-four years must be admitted as a strong argument in its favour. However, in our opinion the wet meter is better calculated to insure the interests of a gas company, whilst the dry meter offers several advantages to the consumer.

The measurement of gas by meter is as simple and as positive as the measurement of liquids by the most ordinary operation; and the volume of the first is capable of being ascertained by the meter with the same precision that liquids are defined by quarts and gallons. There is, however, a very important difference, inasmuch as with liquids, when ordinarily measured, any interruption in the delivery is not material, but with gas the flow must be exact and continuous. The slightest obstruction in the instrument would cause a disagreeable interruption in the supply of gas; consequently the lights would vary, or perhaps be altogether extinguished. Therefore, in addition to measuring, the meter must be self-acting; and, in order that the supply of gas may be continuous and perfectly uniform, it is remarkably delicate in its construction.

The wet gas-meter may be described as simply consisting of four peculiarly formed gas-holders, each of which represents the fourth part of a cylinder; these are all attached to a shaft, with which they revolve. These gas-holders, with their shaft, are placed in a closed tank or outer case, supplied to a certain height with water, and as they revolve each of them is filled with gas in rotation, which gas is expelled by the action of the holder or chamber succeeding it; or, in other terms, each chamber on being filled with gas, causes the preceding chamber to be immersed in the water, and the gas to be expelled therefrom to the burners.

The annexed figure represents a section of the measuring part of a wet gas-meter; *m m m m* is the outer case; K K K K is the revolving measuring wheel attached to its axle *a*, which works in suitable bearings, as shown in Fig. 54. The wheel is divided by the partition plates, *p p p p*, which are slightly inclined, so as to offer little resistance to the water, into four distinct measuring compartments, or as termed four gas-holders, as Nos. 1, 2, 3, and 4. The wheel is immersed in water, contained in the case, to some distance above the centre, as shown by the dotted lines, and by a very ingenious contrivance the gas always enters the vessels in succession at the side B, in the front of the wheel, and by its force presses between the surface of the water and the side of the partition *p p*, as in the case of the gas-holder already described. Thus by these means the vessels are filled with gas in succession, when the wheel revolves in the direction of the arrows, and the gas is expelled simultaneously from the vessels at the side c,

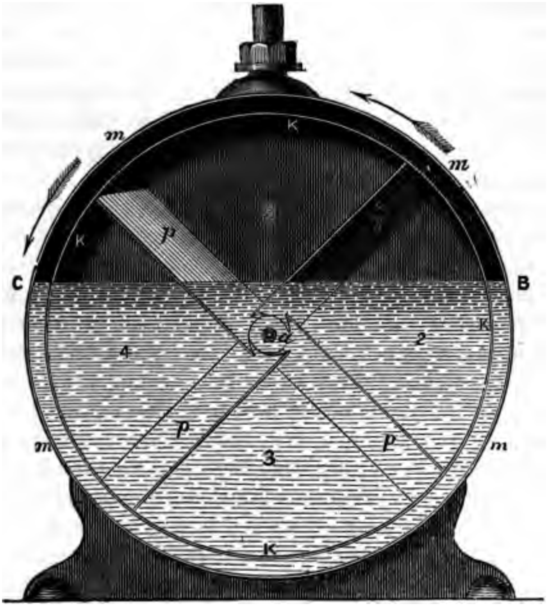


Fig. 54.

at the back of the wheel. This action continues so long as the gas passes; and on each chamber arriving at the centre, as occupied by that numbered 1, it is then filled with gas, and in that position both its inlet and outlet are sealed by the water; but as the wheel revolves, the outlet of that chamber becomes unsealed, when the gas issues to the burners. Hence the capacity of one revolution of the wheel being known, it is evident that by simple mechanical means the quantity passing can be recorded on the dial or index of the meter, with unerring exactitude.

The measuring wheels of gas-meters are of course made with great accuracy, and vary in size according to the number of lights they are destined to supply. Their capacity is generally so calculated that when the maximum of lights is burning, each light consuming at the rate of 6 feet per hour, the wheel will make 120 revolutions per hour. Thus a meter for ten lights is estimated to deliver 60 feet per hour; therefore, the contents of each revolution of the wheel is equal to half a cubic foot, and it follows that this would have to be filled and emptied, or revolve, two hundred times before 100 feet would be indicated on the dial of the index. Hence by these means, when certain precautions are observed, the meter registers with unerring exactitude during many years, until rendered useless from decay.

The train of wheel-work giving motion to the hands on the dials is very simple, as each pinion works into a wheel which contains ten times as many teeth as itself. The ordinary index registers hundreds, thousands, and tens of thousands, while the units of feet are indicated on a revolving cylinder within the index-box of the meter.

Fig. 55 is a cross section of a meter. *k k* is the wheel or drum enclosed in the case, and supported by its axle working in suitable bearings. There is a rectangular box attached to the front of case; in which is a pipe, *l*, for the admission of the gas, the passage of which is indicated by the arrows; the egress pipe is marked *i*; and the meter is charged with water to the line *h h*.

In the front part of the wheel is a hollow disc with an orifice in its centre, through which passes the bent pipe *l*, but without either touching the disc or the axle. The orifice is sealed by the water. Thus the gas, on entering through the inlet *a*, passes into the square box, and thence by the bent pipe into the hollow disc, and so into the four measuring chambers of the wheel in succession, the outlets of which are on the opposite side. Thus the disc separates the inlets of the chambers from the outlets.

Fig. 56 is a front view, showing the details of the contents of square box. *f* is a float similar to that used in water cisterns. On the top of this is attached a valve connected with a lever; and when there is an insufficiency of water in the meter, the float descends, closes the valve, and so obstructs the passage of the gas until the proper quantity of water is supplied. The pipe *c*, through which the gas passes, is level with the water-line, and any excess of water flows down this into the waste-box, *d*, from whence it can be withdrawn from the pipe *e* by the screw.

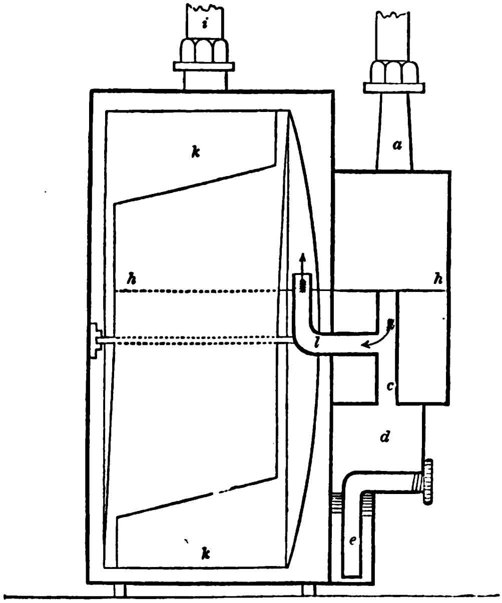


Fig. 55.

Meters, when worked beyond a certain speed, require an increased pressure to drive them. Under these circumstances they indicate slightly against the company, and have a tendency to inconvenience the consumer by suddenly extinguishing the lights, through the float falling and shutting the valve; therefore a meter ought never to supply much more gas than the quantity for which it is destined. The number of burners furnished by a meter is not essential; but the quantity of gas which passes: thus, a meter for 10 lights, or 60 feet per hour, will be able to deliver gas for 20 burners, each consuming 2 feet per hour, or any number in the same proportion, and, as shown, only indicates the volume of the gas passed.

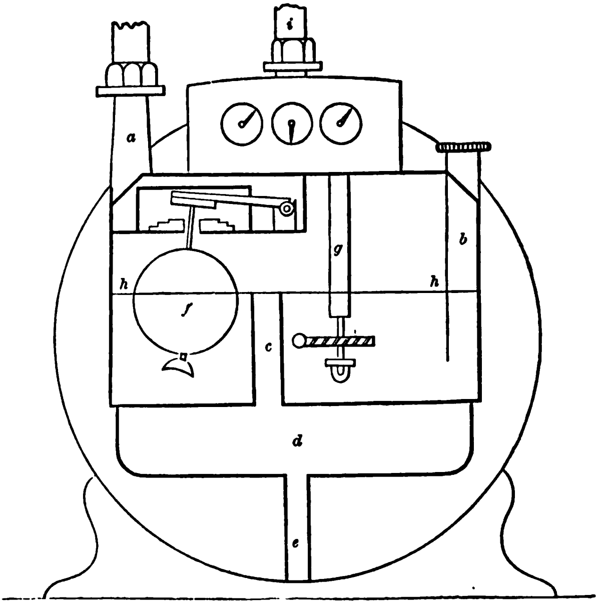


Fig. 56.

On referring to Fig. 54 it will be observed that the part of the measuring vessel nearest the axle is defined by the height of the liquid; therefore by the addition of water the capacity of each of the chambers in rotation must be diminished, or by abstracting the water it would be increased. The first contingency being detrimental to the interests of the consumer, the latter to the prejudice of the company; and if no remedy existed to avoid these evils, the gas-meter would be a very imperfect instrument.

In order to prevent the gas passing when there is an insufficiency of water, the meter is provided with the float already described, which shuts off the supply whenever the water is below its proper level, thus protecting the interest of the company; and any excess of water, which would be detrimental to the consumer, falls down the pipe *c* into the waste-box *d*, and should it not be withdrawn, in time the supply will be stopped. By these simple means the interests of both buyer and seller are secured.

Formerly the degree of accuracy now attained in insuring the proper water level, and the rigidly correct registration of the meter, was not considered. Meters at one time were made in such a manner that, although correct at the proper water line, they could be caused to vary materially either against the company or consumer, by the subtraction or addition of water; but as the instrument was in the custody of the latter, he was always in the position to prevent an excess of water remaining in the meter, and, if so disposed, he could take advantage of the facilities afforded to abstract it.

A few years ago the attention of the public was called to this defect in the gas-meter, and, the worst intentions being assumed, considerable agitation existed on the subject, when the intervention of Government became necessary; and, accordingly, an Act of Parliament was passed, *forbidding* the sale of all meters which by any means could *be made to* vary more than two or three per cent. from the correct standard, which range was allowed for a certain amount of evaporation of water from the meter.

Subsequently some manufacturers surpassed the parliamentary conditions, by making gas-meters even more perfect than the Act required, by constructing them to maintain an unvarying water line, so as to measure strictly accurate. These instruments are called compensating meters, signifying that they compensate for any loss of water that may take place. Fig. 57 is a front view of a meter of this class, as manufactured by the firm of A. Wright & Co., Westminster. In the front part of the square box there is a separate reservoir containing water to supply any deficiency in the meter; and all excess passes to this reservoir. The supply is effected by the shaft of the toothed wheel, in revolving, giving motion to the scoop A, which lifts a quantity of water from the reservoir, and conveys it to the interior of the meter, thus maintaining the surface of the water continually at the same level, and, in consequence, the *measurement* is strictly correct.

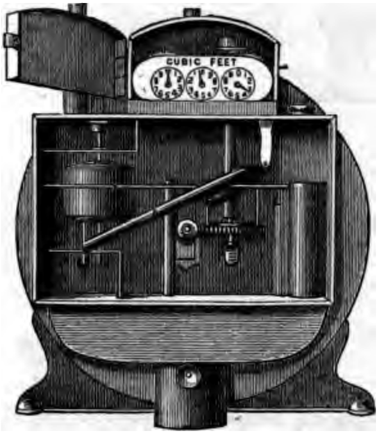


Fig. 57.

Another means of attaining the same result is by the beautiful invention of Messrs. Sanders and Donovan, which is remarkable for its simplicity and ingenuity, and based on truly scientific principles.

Fig. 58 represents a meter with this improvement. B is the outer case on which is fixed a circular case, replacing the square box already mentioned. A is an air-tight vessel, in reality a float, fixed on an axle *x*, working freely in its bearing *a*, so that it can make nearly half a revolution. When there is an insufficiency of water the float hangs in the position shown by the dotted lines, and the *plug b closes* the valve attached to box *c*, and impedes the *supply of gas.*

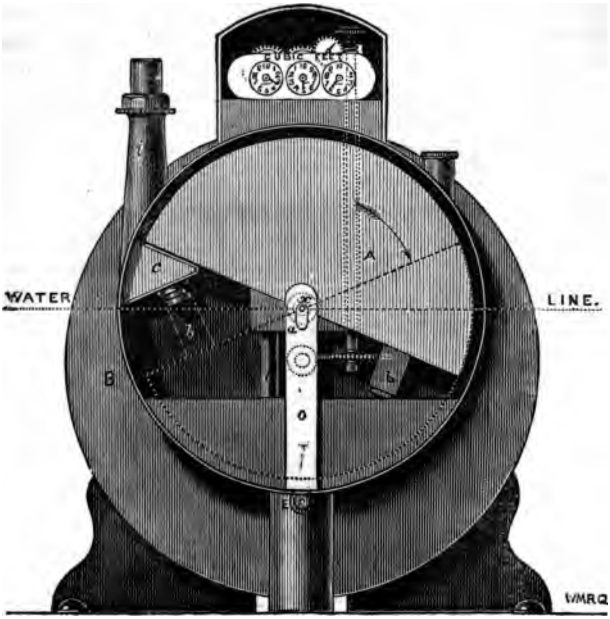


Fig. 58.

But on the meter having a proper supply of water, the float slightly changes its position and opens the valve for the passage of the gas; when, if more water be added to allow for evaporation, the float gradually rises until assuming the position in cut, the level of the liquid in the meter always remaining without the least variation.

In the course of time, any evaporation that may take place is compensated by the float descending in the direction of the arrow, when by means of its bulk the level of the water is maintained at the same height, and on the float being no longer effective the passage of the gas is closed.

The action of this compensator is a combination of several principles of mechanics, and accomplishes the desired effect without the aid of any motive power from the meter.

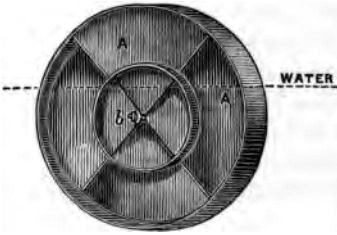


Fig. 59.

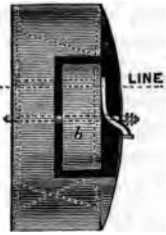


Fig. 60.

Meters are also constructed, where the measuring drum is caused to float, and it has been proposed to float the entire meter and case in a separate vessel, but this has not come into use.

Innumerable patents have been obtained at various times for improvements in the wet meter, and of these the most important is unquestionably the invention of Messrs. Warner and Cowan, by which the instrument is practically correct in its measurement under all the changes of water level to which it may be subjected. This invention consists in altering the ordinary meter wheel A A in such a manner as to place within it a much smaller wheel, *b*, as shown in elevation, Fig. 59, and also in side view, Fig. 60.

The smaller wheel has its partitions placed in the opposite direction to those of the larger wheel. Thus in revolving the smaller wheel acts as an exhauster, and continually expels a quantity of gas as it issues from the outlets of the larger wheel back to the hollow cover to be again measured. Hence on observing the drawing it is obvious that in proportion as the water level descends, by which the chambers of the larger wheel are augmented in succession; the chambers of the smaller wheel at the same time are increased in capacity; when the excess of gas delivered by the larger wheel beyond the true quantity, is returned by the smaller wheel to the hollow cover to be again measured. By these simple means practically correct measure is assured under all the variations of the water line, which permits of a large range for the float, and avoids the chances of extinction by no means uncommon with other meters; particularly those of small capacity; and which is effected without any auxiliary beyond the wheel of the meter.

To avoid as much as possible the loss by leakage, it is always the interest of gas companies to have the pressure in the mains as low as possible, consistent with an efficient supply to their consumers; and in small towns, where there is no consumption during the day, a pressure of one-tenth, in the lowest part of the district, will be sufficient to keep the air from entering. But there are cases where, in order to supply one or two consumers, the pressure has to be kept on continuously, which occasions great loss of gas by leakage. This evil is avoided by attaching a motive power meter, hereafter described, to the premises requiring gas, when, if the pressure in the main be only one-tenth, by this instrument it can be increased so as to give an abundant supply where necessary.

CONTINGENCIES ATTENDING THE USE OF THE CONSUMERS' WET METER.

When there is an insufficient quantity of water in the meter, the float falls, closes the valve, and stops the passage of the gas, sometimes suddenly putting premises in total darkness.

Should there be an excess of water, it overflows into the bottom box, and eventually obstructs the bent pipe *l* (Fig. 55), when the supply of gas also ceases. Therefore, in the event of an extinction, the first step to adopt is to remove the plug of the bottom box and allow the water to flow; should the gas then not pass, water should be poured into the meter until it flows from that plug; and on this ceasing the lighting may be renewed.

Sometimes, when the meter is in an exposed locality, in the depth of winter, the water within it freezes, and the passage of gas is obstructed. Under these circumstances, a quantity of boiling water should be poured into it by the side plug *b* (Fig. 56), and at the end of a quarter of an hour the surplus water should be withdrawn by the bottom plug, when the evil will be remedied. In cast-iron cased meters, by adding a little salt, to the water, the freezing is prevented. This, however, should not be used with tinned-plate cases, as they are rapidly destroyed by the salt.

When a meter is inclined at the base to the left, it registers very slightly in favour of the consumer. If placed in the opposite direction, or tilted backwards, as water is required to be added to keep the float open, it registers against him. But when the meter is tilted forward, often even at a very slight angle, and on allowing the water to flow from the bottom plug, *the gas passes without being measured and the meter is rendered quite ineffective.* There are some unscrupulous gas fitters who make a point of instructing consumers respecting this method of defrauding gas companies, therefore it is only desirable that all connected with the manufacture and distribution of gas should be made acquainted with this, the greatest defect of the wet meter.

THE MOTIVE POWER METER.

The motive power meter in construction, is almost identical with the ordinary consumers' meter. The difference between them consists in one point only, for whereas the latter derives its force or power of action from the passing gas; the motive power meter, on the contrary, possesses a power in itself, which is communicated to it by a weight connected by a cord to the shaft of the wheel.

As usually made, the shaft of the wheel of the motive power meter protrudes a short distance through a stuffing-box, beyond the back of the case. In the simplest form of this apparatus, a wide pulley is connected to the shaft by means of a ratchet, and round the pulley is wound a cord, which passes over a roller situated at a convenient height, and to the other end of the cord is suspended a weight. Thus, in proportion to the weight, and the size of the pulley, and the meter wheel, so will be the pressure given, which is precisely similar in action to a common exhauster. The motor will be recognised as similar to that of an ordinary clock, for as the pulley is loose on the shaft, and is retained only by the ratchet, when raising the weight, it is lifted to the desired height without interfering with the meter. There are various modifications of this principle applied alike to giving extra pressure to the gas beyond that it receives from the works; as well as for exhausting air, and expelling it through a vessel charged with the spirit of petroleum, and other hydro-carbonaceous compounds, by which light is obtained, similar in its nature to gas; which is the subject of another chapter.

THE DRY METER.

This instrument has undoubtedly some important advantages; requiring no water for its action, there is no possibility of the passage of the gas being obstructed by frost, nor are the pipes liable to be stopped by the vapour of the water condensing in them. The dry meter does not, like the other, demand a periodical attention, either to add or abstract water, nor is there the probability of the lights being suddenly extinguished from an insufficiency of that liquid.

Such was the prejudice existing against the use of dry meters about thirty-three years ago, that very few gas companies could be induced even to try them. It was feared that the flexible material entering into their composition would speedily decay, whereas experience has demonstrated that this, when properly prepared and arranged, is the most durable part of the instrument. The dry meter was then considered of such extreme delicacy of construction, that its durability must of necessity be very limited. However, experience and time have gradually dispelled these notions, and that instrument has now become a formidable rival to the other. As a proof of their general adoption at the present day, it may be stated that several manufacturers make only the dry meter, whilst every wet meter manufacturer in the United Kingdom, as well as most of those in America, construct dry meters. However, in France—where to the present time the utility of the telescopic holder is ignored—the dry meter is not recognised.

The first record of a dry meter is met with in the patent of John Malam, dated 1820, in which he adapted a series of bellows combined together to a common shaft, with a rotary valve in the centre; the gas being expelled by the weight of the flaps of each bellows in succession. The plan, however, was not practicable, nor was it ever carried into effect.

The principle of the dry meter will be best understood by referring to the action of the common bellows. When the upper leaf of this well-known domestic appliance is raised, an exhausting power is produced in the interior of the bellows, which raises the valve in the lower flap, and the air enters. But on the upper flap being depressed, the valve is immediately closed, and the air is expelled through the nozzle of the bellows. If we now conceive the upper flap to be attached to clock-work, so as to register the number of times in succession the bellows has been filled and emptied, it is evident that if its capacity at each stroke were known, then we could obtain the means of measuring the air which has passed in, and out of the bellows.

In the dry meter, gas is measured by the alternate expansion and contraction of chambers, each of which may very aptly be compared to the expanding and contracting of the bellows. These chambers are varied in number and shape in different kinds of meters. For example, in the first dry meter made, there were two chambers separated by a flexible division, thus as the gas was received on one side a corresponding quantity was expelled from the other side of the flexible division. In Defries' dry meter, which at one period was the only one manufactured, but is now unknown, the vessel, or outer case, was divided into three distinct compartments, each of which was subdivided by a square flexible leather partition, strengthened by tin plates, forming, when distended, a square pyramid; and by the action of the gas, these flexible partitions were distended first on one side of its vertical plane and then on the other, so receiving and expelling the gas; the number of times the partitions were distended, or the quantity passed, being recorded on the dial.

The dry meter now universally employed was invented by Mr. Richards when in the service of the Chartered Company, and patented by him in 1844, in conjunction with Mr. Croll, who was then superintendent of the Brick Lane Station of that company. The particular points of the invention consisted, firstly, in so constructing the meter as to obtain a steady light from the two partitions or diaphragms, which had previously been attempted but never accomplished. By forming each diaphragm of a large disc, surrounded by a belt of leather so placed as to be subjected to the minimum of wear and tear; and to this point undoubtedly the durability of the leather is entirely due. By employing the means of keeping the discs always in the same planes; and, lastly, by having two slide-valves in connection with the two diaphragms. However, through his unfortunate association, the inventor of the meter, after bringing it to bear, and making upwards of one thousand of them with an incredibly small capital, never derived any benefit from his invention.

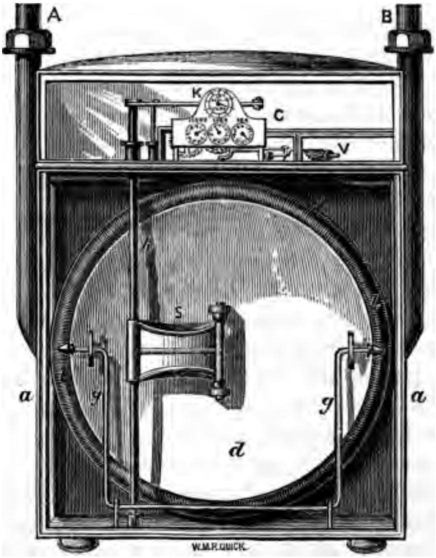


Fig. 61.

The meter in question as now constructed varies from that originally patented only in its outer case, and is represented in elevation with the front part glazed in Fig. 61. As usually made, the meter consists of a rectangular tin plate case *a a*, divided into an upper chamber *c*, which contains the valves and gearing for the ingress and egress of the gas to and from the measuring chambers, and two lower chambers, each of which has its corresponding "bellows," as it is sometimes called.

Each of these bellows is formed by a large disc *d*, supported and guided by the flag-piece *s* and the guide *g g*, which allow it to pass with freedom through the desired distance and keep it always in the same plane. A flexible leather band *l*, hermetically secured to the disc, as well as to a ring soldered to the central partition, completes the bellows as shown in elevation in the drawing. The gas on entering one of these flexible chambers expels an equal quantity of gas from the outer chamber to the burners, and when the disc passes through a certain distance, the position of the valve is changed. The action is then reversed, when the gas enters the outer chamber and expels a like quantity from the interior of the "bellows."

There are two of these bellows, and consequently four measuring chambers, which receive and expel the gas continually in succession; A is the inlet, the gas after being measured passes off by the outlet B, and as already explained with the wet meter, the capacity of the measuring vessels being known, the number of times they have been filled and emptied, or the quantity consumed, is communicated to the index, K, by means of wheel-work.

The action of the metallic discs in this meter has been compared to that of the piston in a steam-engine; and there is certainly a considerable analogy if the comparison be made with the horizontal cylinders of a locomotive engine, in which the motion of the pistons is precisely the same as that of the discs in this kind of meter.

A common defect with the dry meter is, that although it may measure correctly with a certain supply, yet when this is much increased, should its valves be set to "close late," under these circumstances the meter will indicate *against* the company, and the variation is often very *considerable.*

CHAPTER XVIII.

BURNERS AND GLASSES.

Effect of Burning Gas—The Different Kinds of Burners—The Argand—The Batwing—The Fishtail—Effects of Excessive Pressure on Burners—Variation in the Degree of Light evolved from Argands—Adamas, Steatite, and Enamel Burners—Glasses—Sugg's Burner—Witham's Burner—The Regulator.

When coal gas is ignited as it issues from a burner or orifice, its hydrogen is consumed at the lower part, producing the blue flame characteristic of it, and the carbon being sufficiently heated, if properly consumed, is liberated in a solid state at the upper part of the flame, where it combines with the oxygen of the atmosphere, again therewith resuming the state of gas as carbonic acid; and according to the degree of heat attained by the innumerable particles of carbon, so will be the amount of light emitted by the gas.

Whenever the flame of gas is unduly cooled, or when the gas is intermixed with a portion of atmospheric air, or when it issues from the burners under great pressure, or when the passages for the gas are obstructed, the light evolved from a given quantity is very materially reduced, and when either of these contingencies is carried to an extreme, no material light is obtained from gas. To all of which points we shall have occasion to refer hereafter.

It is almost needless to say that the points from which the gas issues at the instant of ignition, are termed the burners. These generally employed for gas-lighting are the argand, the fishtail, and the batwing, and under certain conditions the single jet is used. The argand takes its name from the inventor, a Frenchman, who, towards the close of the last century, introduced a most important improvement in lamps, by causing the wicks to be made in a circular form, with an orifice for the admission of air at the centre, and surrounded by a glass chimney. By these means a current of air was caused to pass and impinge on the interior and exterior of the flame, which insured a more perfect combustion of the oil, whilst the flame and light could be augmented to a very considerable extent.

The argand burner was applied in the earliest days of gas-lighting. In the first instance it was constructed in imitation of the oil lamp burner, by having a narrow ring or space for the emission of the gas, but subsequently it was formed, as now employed, by an annular plate on the top, pierced with a number of holes, through which the gas issued at the point of ignition; but as we will be enabled to explain hereafter little was practised for many years to produce an economical and effective argand burner. The other burner then used was the cockspur, which was formed by three single jets placed at right angles to each other, but this, on account of its inferiority, has long fallen into disuse. The batwing burner is formed by a slot across a nib, and by its pressure the gas in its passage on ignition, assumes the form of a flat sheet of flame. The union jet or fishtail has a flame somewhat similar to the last-mentioned, which, however, is obtained in a different way. To explain the action of this burner, if we suppose two single jet burners connected by flexible piping, and to be brought in close contact with each other at a certain angle, the two jets on impinging against each other, produce a flat flame somewhat resembling in form the tail of a fish, whence its name. However, by the action of the two jets uniting it is also called the "union jet;" and from the fact of its being first produced in Scotland it is also named the "Scotch burner," and finally we have known it to be designated the "Manchester burner," but for what reason we cannot say.

In the fishtail burner two holes are drilled at a certain angle, from which the gas issues, and as the flames impinge against each other, the flat flame is produced at right angles to the line of the orifices.

The single jet is formed by the gas issuing from a very small orifice, which, however, for the quantity of light yielded from any given quantity of gas, is very expensive; for this reason it is almost abandoned for the purpose of lighting, but is applied under certain conditions where a small flame is required.

Although scientific men directed their attention to the construction of burners some few years after the establishment of gas, and entered very minutely into the theory of combustion, and laid down some most valuable rules concerning the best form of burners, this information during many years was entirely disregarded. And we are led to the conclusion that the errors committed in the construction of burners demonstrate that the opinion existing at one time, was, that no matter how the gas might be burnt, no matter the size or number of the orifices of the burner, that from a certain quantity of gas a given quantity of light would always be evolved. However, this idea is entirely erroneous, as gas may be consumed in such a manner as to give its maximum degree of light, or to yield no light whatever.

In order to make these assertions evident, if we employ gas of such a quality, that with an argand burner, consuming say 6 feet per hour, the light of 20 candles is evolved, which we may assume to be the maximum amount of light to be derived from it. But if the same quantity and quality of gas be consumed in a Bunsen or atmosphere burner, by which means a quantity of air is intermixed with the gas, then a blue flame is produced, but practically devoid of light. The same effect is obtained by having an argand or other burner with very small orifices demanding a considerable degree of pressure to supply the gas, when under either of these conditions no light is evolved by the gas. The difference between the two being, that in the first case the air is caused to combine with the gas before ignition, and in the latter case it combines during ignition. Or as generally believed, the surrounding air cools the flame and prevents it attaining the high degree of temperature essential to produce the full amount of light.

As the pressure of the gas at the point of emission beyond a certain degree increases, so does the amount of light evolved from any given quantity of gas decrease. Thus if an argand be so made that 5 feet of gas per hour will issue at a pressure of one-tenth of an inch or less; then the light of, say, 14 candles will be obtained. If, however, we employ exactly the same form of burner and chimney but diminish the size of the orifices to that degree that six-tenths of an inch pressure will be necessary to expel the 5 feet of gas, then, instead of getting the light of 14 candles, we get only that of 7 candles, and by further diminishing the orifices and increasing the pressure to a certain degree, no light is yielded by the gas.

From the preceding we acquire the knowledge of one of the elements essential to the construction of all burners, that is, to avoid excessive pressure at the point of issue. But with the argand there are other considerations such as the areas of the centre, and the annular orifices for supplying the air; the height of the chimney; also the regularity in the dimensions of the holes in the burner; all of which influence materially the light evolved from a given quantity of gas.

Again, if the flame of an argand burner be very irregular and rugged in appearance, a large amount of the available light that could be derived from the gas is lost. Lastly, with the best constructed argand, if the proper chimney be replaced by another materially longer, a strong current is created, when the flame is cooled and the degree of light emitted by the gas diminished.

From the preceding we learn the care to be observed in the formation and the use of the argand burner; that according to its construction and the manner it is employed so will be the amount of light evolved from any given quantity of gas; or in other language, when the quantity of light evolved is considered, the cost of the gas will depend, in a great degree, on the description of burner employed.

We may briefly describe a good argand flame, as one that is of uniform height throughout, without any marked trace of the numerous jets which compose it; that is, the flame should be one bright mass, except at the bottom, where there will always exist a blue ring; and no matter the quality of the gas consumed, these are the requirements of a flame from a good burner, and from which the gas should issue at a pressure not exceeding two-tenths of an inch. Hence we learn that with poor gas, the orifices of the burners must be larger or more numerous than would be required for rich gas, in order that the jets may combine together.

Argands are generally made to consume five feet of gas per hour, and they only give the full amount of light the gas is capable of evolving, when burning the maximum quantity for which each burner is made. Moreover the light diminishes materially in proportion as the quantity of gas is reduced; as shown in the following table of the light evolved from an argand under different consumption of gas.

When consuming	5	feet per hour,	the light is equal to	12	candles.
„ diminished to	3½	„	„	4·5	„
„ „	2½	„	„	1·2	„
„ „	1½	„	„	0·2	„
„ „	1	„	„	0·02	„

It follows therefore that, in order to obtain the maximum amount of light from argand burners, the full quantity for which they are made should be consumed by them, and whenever it may be desirable to introduce economy, it is better to have a limited number of burners of the larger dimensions, some of which may be extinguished when desired, rather than have a number which are checked to only a portion of their full consumption. The light from a given quantity of gas when consumed in the batwing or fishtail, does not vary in the same degree, when the flame is reduced, as the argand. Thus, if we suppose either of these burners to yield the light of ten candles when consuming five feet per hour, on reducing the supply of gas to 2½ feet the light of 2·5 candles will be evolved.

With the batwing and fishtail burners there are not so many considerations to attain excellence, as with the argand. But both the burners in question demand a greater degree of pressure at the point of issue, which is about $\frac{6}{10}$ of an inch, for the proper development of the flame. When the pressure is less than this, the flame flags, becomes smoky and emits diminished light. If on the other hand, however, the pressure be excessive, then the gas passes off uselessly, and it may be increased to that degree that no light is yielded by the gas. As an illustration of this, let us take a batwing or fishtail burner, which is made to consume five feet per hour, at which point the gas produces its maximum amount of light; now if seven feet per hour be forced through the burner, the light instead of being increased is actually decreased, and by further increasing the supply of gas considerably, a roaring flame is the result and practically devoid of light. These are all plain statements which any one can verify, and show the necessity for observing care in the choice of burners, as well as in the means of employing them.

The agitation created by the recent display of the electric light induced gas companies to demonstrate that equally large volumes of light could be obtained with gas as with electricity. For this purpose Mr. Sugg very opportunely produced large argand burners, with three or four concentric rings of holes for the emission of the gas. A special lamp was made for these burners, as represented in Fig. 62: the upper part is of white opal glass, which prevents the light being diffused into the atmosphere above; it also serves as a reflector, and throws the rays to the ground beneath. The largest of these burners consumes about 45 feet per hour, and yields the light of 200 candles. Their elegant appearance, together with the splendid light evolved, has caused these burners to be adopted to a very large extent in many towns and cities of the Kingdom. Very recently Mr. Sugg has changed the shape of the lantern to a spherical form, the upper part of which like that described is opal. By the alteration the flame is seen to greater advantage, and the lantern has a more elegant appearance.

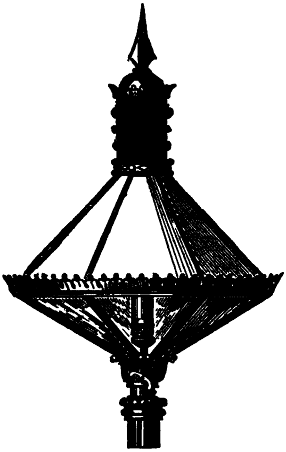


Fig. 62.

Another description of burner suitable for giving a large quantity of light is that invented by Mr. Witham, and consists of a number of small fishtail burners placed in concentric rings. At the lower part is a cone which admits the supply of air, and at the upper part immediately above the jets is a talc chimney, by which a current is formed. This is in reality an imitation of the concentric ring argand, and gives a splendid light equal to about four candles per cubic foot of ordinary sixteen-candle gas, and it is well adapted for large areas, such as docks, squares, very wide streets, or where several roads meet.

Small burners, and particularly fishtail, are objectionable on account of the diminished light yielded by a given quantity of gas when they are employed. An instance of this recently came under our notice, where in a shop window five fishtail burners of the smallest description were used, no doubt with the view of economy. These were enclosed in glass moons, but the whole combined did not yield the light of one candle, whereas with a proper burner, the same gas would have given the light of six or eight candles. Under these circumstances the fault is frequently laid to the gas, and not to the means adopted for consuming it.

Formerly, burners of all descriptions were made of iron, but as this metal corrodes very rapidly, and by its corrosion obstructs the passages for the gas, and diminishes the amount of light evolved—for these reasons the iron burner is objectionable.

Within the last twenty years, other materials have been introduced to replace the iron burners, whether applied in the construction of the argand, or others. These are the "Adamas" of Leoni and Co., the "Steatite" of Sugg, and the "Enamel" of George Bray and Co.; and with burners of these materials at our command, which neither corrode nor break, the orifices of which cannot be enlarged, together with their very moderate cost, the use of iron burners should be discarded by every gas company in the world; for, as already stated, by the corrosion of the iron the passages for the gas become obstructed, and a considerable degree of light is lost, which evils are avoided by the burners mentioned.

It is foreign to our purpose to recommend any article or firm, unless when there exists a marked superiority in the production, or process, or apparatus, and which can only be procured from any particular house; under these circumstances we feel justified for the benefit of the gas profession at large in sometimes mentioning names.

The batwing burner, on account of its flame extending in width under augmented pressure, is not suitable to be enclosed in a globe, but it is generally employed for the public lamps simply because it yields a greater degree of light for equal consumption of gas, than the fishtail. The latter is very commonly used in dwellings, enclosed in globes, by which, however, the light evolved is diminished by two distinct causes, namely, the nature of the material composing the globe, and the dimensions of the orifice for the admittance of air at its base.

The degree of obstruction of light with different kinds of globes, is represented by Mr. Wood of Hastings and others as follows:—

Light	obstructed by a	clear glass globe . .	about	12	per cent.
„	„	clear globe with slightly ground flowers . .	„	24	„
„	„	globes of about the usual pattern . . .	„	35	„
„	„	globes ground all over .	„	40	„
„	„	opal globes . . .	„	60	„
„	„	painted opal globes .	„	64	„

Hence from the preceding, we gather that with an ordinary clear glass globe nearly one-eighth part of the light is absorbed by the glass and lost. That when globes are ground all over, a loss of 40 per cent. of the light is sustained, and with opal globes such as are very generally used, no less than 60 per cent. of the available light is absorbed; or in other language, if we imagine the price of gas to be 4s. per 1000 feet, and if the quantity of light obtained by opal globes is duly considered, then by their use the consumer voluntarily increases the price of his gas to 10s. per 1000 feet.

The globes or moons for fishtail burners have the lower orifice about 2½ inches, and the upper 4½ inches in diameter. The effect of this is, that a current of air is always rushing in at the bottom to replace the heated air, which is continually escaping from the interior of the globe. Consequently, this current impinges upon the flame and cools it in such a manner, that if four feet or six feet of gas issues from a burner enclosed in a globe of this description, no difference is observed in its flame, and by these simple means frequently one-third of the gas consumed passes away in waste.

As a partial remedy for this defect, the orifice in the bottom of the globe should be considerably increased, in fact it should approach the other in size, and if this system were generally adopted, the yield of light from burners would be most materially increased.

However, a most essential point in the combustion of gas, whether in lighting (and particularly with argand burners), or for cooking, is to employ means to counteract the variable pressure at which the gas is delivered in the majority of places by the change in the pressure at the company's works. This is accomplished by the use of the regulator already described, and whenever a proper instrument of this kind is employed, it must be attended with considerable economy, as by it the pressure is reduced to that degree most essential for obtaining the greatest amount of light from the gas. Wherever it is used, however the pressure may vary in the company's main, by the regulator it is always retained alike on the consumers' premises.

Since the preceding was in type we have been made acquainted with a system adopted by the accredited burner manufacturers, Messrs. George Bray and Co. of Leeds, for obtaining large volumes of light from 30 to 400 candle power, suitable for lighting extensive areas. This consists in combining three or more flat-flamed burners in close proximity to, but without touching, each other. These are enclosed by an ornamental lantern, which is so arranged that the necessary current of air, passing upwards, insures steady clear flames, and at the same time any storm, however violent, is prevented from affecting the steadiness of the burners. By this arrangement a greatly increased degree of light is obtained from any given quantity of gas.

CHAPTER XIX.

THE VARIOUS APPLICATIONS OF GAS FOR HEATING, COOKING, AND OTHER PURPOSES.

Warming Stoves—Cooking Stoves—Boiling Stoves—Hot Plates—Kitcheners—Necessary Precautions—The Gas Engine—Various Uses of Gas.

WITHIN the last few years gas has been applied with a remarkable degree of success to heating apartments, halls, offices, shops, conservatories and similar places, as well as to cooking, and other domestic and industrial purposes, by which the mains are brought into active operation during the day-time, with a considerable increase to the business of gas companies; and this work would be incomplete if these appliances were not described.

Although when lighting by gas was first projected, gas was also proposed for some of the objects under consideration, many years passed away without any steps being taken to carry them practically into operation; and afterwards, when this was attempted, during a long period failure succeeded failure, and the successful adoption of gas for heating and cooking, dates only from the last fifteen years.

WARMING STOVES.

Of all the kinds of stoves for warming apartments, among the simplest is that represented in the annexed Fig. 63. This consists of an ornamental wrought-iron cylindrical vessel, containing a ring of gas jets, which when ignited yield sufficient heat to maintain the atmosphere of an ordinary sized room at an agreeable degree of warmth in the depth of winter. Other stoves of various designs, constructed of different materials, such as cast iron, terra-cotta, and china, are also made for the same object, which are of that degree of elegance as to render them suitable for any locality where ornament is desirable. Where gas stoves are used it may be necessary under some conditions to carry the products of combustion away from the apartment by a small pipe which ought never to exceed two inches in diameter. Thus, one of the great benefits accruing from the use of gas-stoves consists in the absence of the draught occasioned by the large chimney of an ordinary house fire, which in cold weather, when the door of an apartment is opened, speedily carries off the warm atmosphere, to the great inconvenience of the occupants.

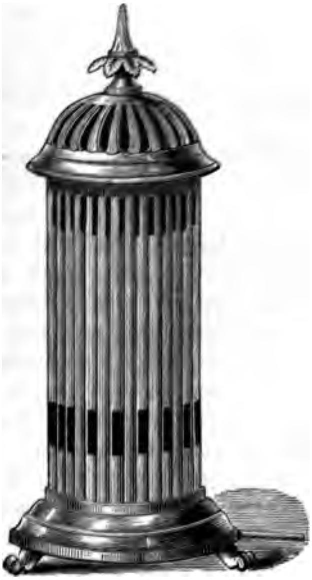


Fig. 63.

Another description of heating stove is represented in Fig. 64, and termed the "cheerful stove;" in this at the upper part a number of gas jets are ignited, the light and heat of which are reflected by the corrugated copper plate, and presents a bright and cheerful appearance. A description of "cheerful stove" has, instead of the corrugated copper plates, embossed plates representing foliage or other subjects, where innumerable projections are required, and in which each projection is a reflector. This stove possesses the advantage that at whatever angle it may be viewed it always presents a bright surface; and the disagreeable flickering of the jets, inherent with the stove previously mentioned, is with this avoided.

Heating and ventilating stoves are also made by which all the products of combustion are conveyed away from the apartment and fresh air is admitted heated to any desired temperature at the moment it enters. These stoves can with every confidence be adopted in the bedroom of the most delicate invalid without the slightest chance of any odour arising, or other inconvenience being experienced from the burning gas; whilst the vitiated air of the apartment is continually being removed and replaced by fresh air from the exterior of the building. Such is the efficiency of this kind of stove, that it is frequently employed in conservatories for months together without the slightest trace of injury to the surrounding vegetation, which is a most crucial test of its salubrity.

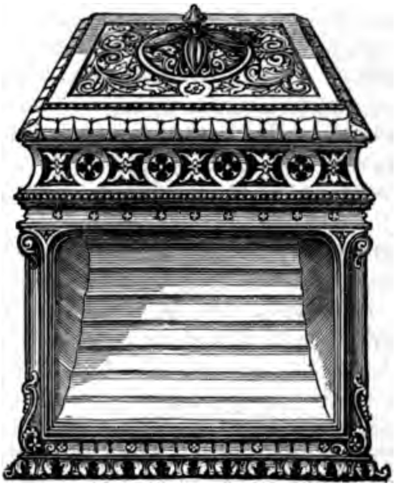


Fig. 64.

Warming stoves are made to suit all classes of society, for the small office for which a stove may be had for about 15s. or 16s., and which office can be maintained at an agreeable temperature during the depth of winter at a cost of about 1½d. per diem for gas.

An excellent contrivance for heating churches, chapels, and other places is applied by Mr. Gill, of Bridgnorth. This consists of a cast-iron frame about 10 inches square, and 4 inches deep, surrounded by a non-conducting material, and covered by a movable perforated ornamental top. This frame is placed just beneath the flooring, so that its cover is level with the surface of the floor.

Within this is a ring "atmospheric burner," which when lighted emits neither smoke nor smell, a quality always possessed by this description of burner. The gas stove described is very effective, and by its position necessarily the atmosphere at the lowest part of a room is heated.

Gas-stoves are also made to imitate the ordinary house fire, or burning logs of wood, and where elegance of appearance is desired, this is furnished by apparatus manufactured of excellent designs suitable for any locality.

COOKING STOVES.

As our space is necessarily limited, we proceed to notice the apparatus adopted for culinary purposes. The simplest of these is shown in the annexed figure, and termed a boiling stove. This consists of a cast-iron stand as represented in Fig. 65, provided with a handle, and in the centre is a circular burner composed of several jets. The apparatus is sometimes attached to a flexible tube in order that it may be portable; but such is its great utility, that in every house where gas exists it should be permanently fixed with metal tube, which avoids all the inconveniences experienced by the india-rubber tube.

The gas enters by the handle, where there are small holes for the admission of air, and in its passage carries with it a portion of atmospheric air. This is called the "atmospheric burner," and is very generally employed alike for cooking as for heating. The mixture of gas and air is consumed in the burner, producing great heat, but entirely devoid of smoke or soot; advantages which render the boiling stove so cleanly and desirable. With this little apparatus, which is about seven inches in diameter, and costs about three shillings, water for the breakfast of a family can be boiled in a few minutes; it is also adapted for innumerable other purposes wherever moderate heat and promptitude are necessary, and we repeat that every house supplied with gas should have this useful appliance.

Combinations of two or more of these boiling stoves are made, which are very desirable in the French *cuisine*, or wherever boiling or stewing operations only are required.

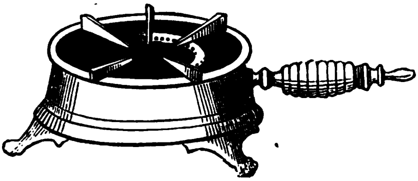


Fig. 65.

Fig. 66 represents one of those apparatuses termed a "hot plate," and consists of a cast-iron frame, having three atmospheric burners similar to that already described, with their corresponding taps. This is about 22 inches long, 16 inches wide, and 6 inches high. They are also made with as many as six burners suitable for an hotel. The prices of these stoves are within the means of all.

Another description of stove which unites the boiling stove with a toasting or grilling appliance is shown in Fig. 67. This is provided with one atmospheric burner only, situated immediately beneath the kettle, and when required for boiling, the sliding valve, which covers the burner (of which the handle is shown) is opened; but whenever it may be necessary to toast or grill, the valve

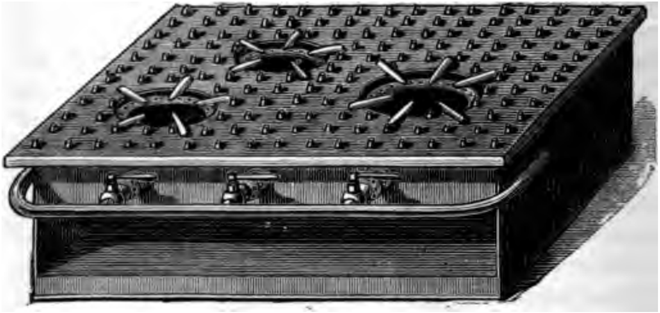


Fig. 66.

is closed when the heat is radiated on to the food. With this apparatus bread may be toasted, or chops, steaks,

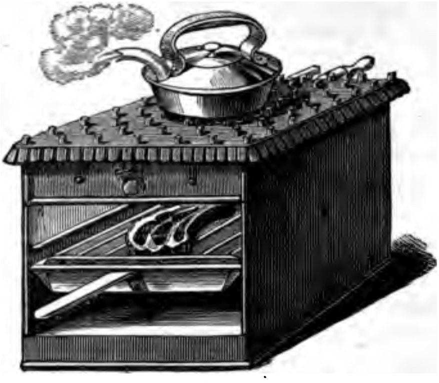


Fig. 67.

and bacon cooked to perfection. The smallest of this class of stove costs about twelve shillings, and the expense of gas for the operation is merely nominal.

cording to another system of stove, a hot plate is
ined with an oven, as shown by Fig. 68, and the
tion of roasting is effected by the heat being reflected,
adiated on to the food; at the same time a current of
continually passing. Thus, all the alleged advan-
of roasting before an open fire are secured. The
is heated by the fire beneath to the requisite
e of temperature, and the hot plate is sufficiently
for two saucepans. This stove can also be applied
warming an apart-
, by removing the tin
tor and grill, and
ituting a copper re-
r similar to that in
in the "cheerful
."

ves are made of the
iption shown in Fig.
capable of roasting
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on, having the oven
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a number of boiler-
ers in the hot plate,
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forming a complete
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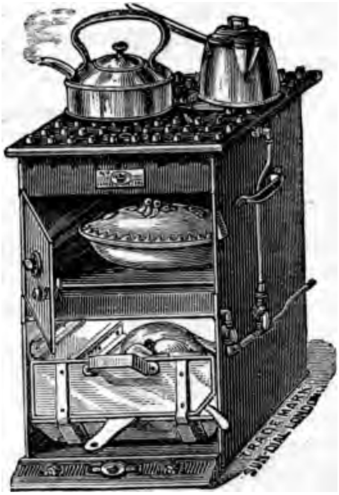

Fig. 68.

family kitchener which
ghly approved of is represented in Fig. 69, and is
rised of the outer casing lined with tiles or other non-
ucting material. At the lowest point are the jets of
nd gas, and in that chamber is suspended the joint to
asted. The heat at the same time passes to the oven
e, in which two pies and a joint are represented.
three boiling stoves complete the apparatus. It should
bserved that a current of air is allowed to pass con-
usly through the stove and oven. We have seen the

most flattering testimonials concerning this apparatus, which have a very extensive sale. There are innumerable other stoves constructed by manufacturers who make this class of business their specialité.

Cooking by gas is now no longer an experimental operation, as the system is practically employed in private families of all classes with the most complete success. It has been introduced into hotels, clubs, and large establishments where food has to be prepared for upwards of one thousand persons daily ; it is adopted in schools, hospitals,

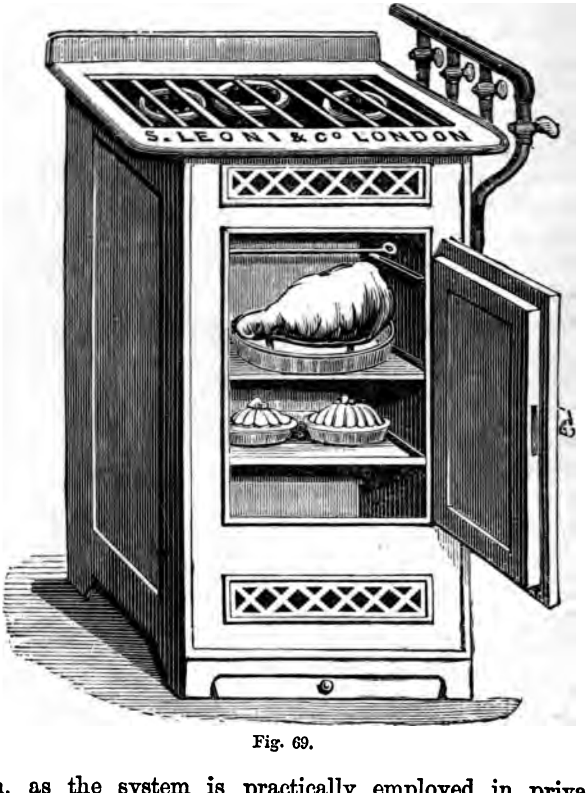

Fig. 69.

barracks, and in all cases gives the most entire satisfaction on the various points of perfection in the operation, economy, and cleanliness.

Mr. Magnus Ohren, who has had vast experience in the matter, as there are upwards of 600 consumers supplied by the company he represents, who have adopted the system of cooking by gas, makes the following observations:—

"Complaints are sometimes made that a sufficient supply of gas cannot be obtained for the stoves during the daytime, but in the majority of cases this is due to the supply pipes being too small. It is recommended that, wherever possible, and especially for cooking stoves, an independent pipe should be carried from a point near the meter direct to the stove. This applies more particularly to low-lying districts; but as the pressure of the gas increases in elevated situations, in such places it may be found advantageous to fix a governor for regulating the supply of gas to the stoves.

"In an ordinary fire-place, the odour from cooking should pass up the chimney; but with gas stoves, *unless fixed in an open fire-place,* the smell, especially in frying, escapes into the room, and is thus disseminated through the house. To avoid this inconvenience, a hood should be placed over the stove with a ventilating pipe to the chimney, or the stove may be placed in an out-building, where the odour from the cooking is less objectionable.

"In lighting 'Atmospheric burners,' care must be taken to turn the gas full on, and afterwards moderate the flame to the intensity required. If the supply is not turned fully on in lighting, the gas is liable to 'light back'—that is, to light *within the tube* without mixing with the air, and thus cause the burners to smoke and smell, and will continue to burn so, however much the gas tap may be afterwards opened; the only remedy is to turn the gas completely off and re-light it. When properly adjusted, the atmospheric burner should give an almost perfect blue flame, which is a guide to the full height. If the burner does not give sufficient heat, the flame should not be increased in height, but a larger burner used, otherwise a smell will be caused by the improper use of the gas.

"Gas stoves should be kept clean by washing them with soda and warm water, and when dry they should be blackleaded; the stoves, if allowed to become greasy, will cause an unpleasant smell."

Although attempts were made to obtain motive power from gas, a long period before it was applied to illumination, and during many years a vast amount of attention has been given to the subject, and innumerable patents obtained in connection therewith, yet only within the last few years has any definite progress been made in the matter. At the Universal Exhibition of 1851, a gas-engine was exhibited which was regarded merely as a "philosophical toy;" however, from that time to the present, the same engine has held its ground with more or less success, and no doubt has led gradually, by repeated improvements, to the present high state of excellence achieved in the *manufacture* of gas-engines.

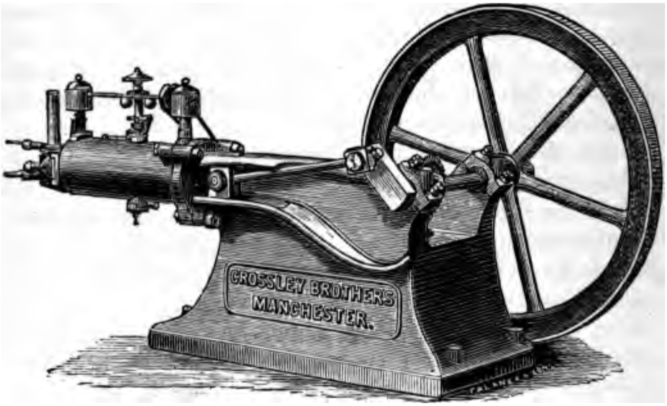

Fig. 70.

Beyond all question, the best description of gas-engine is that manufactured by Messrs. Crossley Brothers of Manchester, which is represented by Fig. 70. This in action, so far as regards the piston and cylinder, crank, and fly-wheel, resembles an ordinary high-pressure steam-engine; but there the resemblance ceases, for with the gas-engine no boiler is required, nor is a skilled mechanic necessary to attend to it. With it there is no fear of explosion, while its security against fire, is proved by insurance companies not increasing the amount of insurance wherever these engines are employed.

The gas-engine is actuated by the ignition of a mixture of gas and air, which is immediately expanded and gives the desired force. One end of the cylinder is open to the atmosphere, and on commencing operations the fly-wheel is caused to make part of a revolution. This draws into the cylinder a certain quantity of air which is followed by a stratum of gas, the compound filling the cylinder. By continuing to turn the fly-wheel the gas and air are compressed, and on the return stroke the gas is suddenly ignited, when the expansion of the air and gas drives the piston through the length of the stroke, and the next stroke is made by the fly-wheel. Thus there are four single strokes of the piston; the first draws in the air and gas, the second compresses them, they are then ignited at the beginning of the third stroke, which is the effective force, and by the fourth stroke the products of combustion are expelled.

These engines have been made in considerable numbers, varying from one-horse to 35 indicated horse power, and are equally as effective as steam-engines, as proved wherever they have been employed, whilst the cost for gas at 4s. per 1000 feet does not exceed a penny per horse power per hour. They are free from noise and vibration, and it is to the interest of gas companies to employ them, if only as specimens for their consumers.

Various descriptions of gas-engines are manufactured, by different firms, giving the force of one man-power and upwards. Indeed, we have recently heard of a gas-engine capable of supplying a power sufficient to drive a sewing-machine, which is sold at a very moderate price.

The other applications of gas are too numerous to mention; but baths and conservatories are heated by it with the most perfect success. Gas is applied for numerous industrial purposes, by copper-plate printers, by tinmen, by jewellers, and various other trades; by laundresses, for heating their flat-irons: and wherever a moderate heat is required, this can be obtained with gas more economically than by other means, whilst the facility of application is always a strong recommendation to its use.

With these statements of the advantages of heating and cooking by gas, its application as a motor, and various industrial uses, it becomes the duty of every engineer and manager of a company to assist in its further development; which accomplished, in the course of time the demand for gas for the purposes in question will add materially to the revenue, and will bring the plant of a company into active operation alike in the height of summer, as in the daytime in winter, at which periods hitherto their mains as well as a portion of their works have been comparatively inoperative.

CHAPTER XX.

GAS EXPLOSIONS.

The Fears of Explosion on the First Establishment of Gas-lighting—The Cause of Explosion—An Explosive Compound not Inflammable under Pressure—Experiments made to prove this—Meters sometimes exploded—The Danger of the Hydraulic Joint of Gasaliers.

WHEN gas-lighting was first proposed, the dangers to be apprehended from explosions were the strongest arguments against its adoption; and several scientific men of the period attempted to reduce these casualties to a positive law, and, among other statements, they asserted that a gas-holder containing 15,000 feet of gas would in exploding be as destructive as ten barrels of gunpowder. As a further proof of the slight knowledge of the nature of gas at the time, Sir William Congreve, with other learned gentlemen, when acting as a royal commission of inquiry on the subject of explosions, recommended that gas-holders should not be of greater capacity than 6,000 cubic feet each; and that they should be surrounded by strong walls, in order to confine the effects of an explosion whenever it might occur.

We can look with satisfaction to the advancement science has made in connection with this subject: for now we know instead of gas being so terribly destructive, that when unmixed with atmospheric air, or oxygen, it is as harmless as regards explosion, as the water in the tank beneath it; and if it were possible to insert a lighted torch or taper into a holder containing gas, instead of the gas exploding, the flame would be extinguished. In other words, gas unmixed with oxygen suffocates flame, and in this state cannot ignite or explode.

That explosions by gas have occurred, and do sometimes even now happen, is well known, but these have been so remarkably few in number, that the extraordinary safety of gas-lighting is as fully established, as the safety of railway travelling under the most careful supervision; however, by treating on these accidents, and describing their causes, is to adopt the proper steps to prevent them.

Explosion is an instantaneous ignition of a mass, and that mass may be solid or gaseous; thus, a mixture of charcoal, sulphur, and nitre in certain proportions, and prepared in a particular manner, form gunpowder; which ignites instantaneously, and the increased volume, occasioned by the solid assuming the gaseous state, is the cause of the force, or power attending the combustion. There are numerous other solid compounds infinitely more explosive than gunpowder, but the simple mention of this will be sufficient as example.

Certain gases, like the solids mentioned, when intermixed in due proportion, are likewise capable of instantaneous combustion; for instance, hydrogen, when intermixed with oxygen, as before stated, in the proportion, by volume, of two of the former and one of the latter, ignites, producing explosion; and coal gas when combined with air in certain proportions is also explosive, which is due to the hydrogen and carbon composing it, entering into combination with the oxygen of the atmosphere, producing water, and carbonic acid gas; and the nearer they approach to the proper proportions for the perfect formation of these compounds, the greater is the force of the explosion. A mixture of seven parts of air and one of gas is considered to be the most explosive compound, but this must depend on the quality of the gas. The generally accepted theory is that mixtures of less than three of air to one of gas, or *more than* eleven of air and one of gas, do not explode.

Explosions from gas are exceedingly rare. By a Divine ordinance the odour arising from gas is generally so repulsive as to awaken in the minds of the most callous a desire to avoid the annoyance, and in so doing the danger is averted.

At one period or other, in some of the largest cities of the United Kingdom, as well as those of the Continent, gas-works have been the scenes of explosions. This has often arisen from a new gas-holder, when nearly terminated and ready for use, having been communicated with the manufacturing apparatus; and it has afterwards happened that through a leaky valve allowing the gas to pass, or perhaps by some careless person thoughtlessly opening the valve, the gas has entered, intermixed with the air in the holder, when by the accidental production of a light the disaster has occurred. Therefore, when new holders are constructed, they should either not be communicated with the manufacturing apparatus until quite terminated, or the pipes should be "logged," or sealed with water, in order that no gas can possibly enter until all is quite ready for use.

But explosions of this nature have occurred when the holder was being first filled with gas; one of the most remarkable took place some years ago, by which the engineer was killed. This arose from a defect in the construction, and want of ordinary caution on the part of the unfortunate sufferer. The facts are simple, for the holder on being charged with gas at the commencement of the operations contained a considerable quantity of air, the two forming an explosive compound, and by a singular fatality it happened that no gas was being made, and the holder was so far bound, or set, as to give no pressure. The engineer, desirous of judging the quality of the gas, very imprudently tried it at an open orifice of comparatively large diameter; the consequence was, the flame entered, the explosive compound in the holder ignited, and occasioned the disaster. Had the gas been tried by an argand, or fishtail burner, the accident would not have happened, as the holes in these are too small to permit the flame to enter.

Explosions have taken place in station meters when newly erected, just previously to their use, arising from causes already mentioned, or by a leaky valve, or unnecessary meddling on the part of the workpeople. On one occasion which came under the writer's notice, a calamity of this kind occurred from the explosive mixture taking fire through the men making the joint with overheated lead. And this suggests the varied opinions as to the possibility of a spark igniting gas. The general opinion is that gas cannot be ignited by that means; and, indeed, it is difficult to be done, but by chance a spark may be produced of sufficient heat to inflame gas.

Accidents have frequently occurred when laying mains; often occasioned by a bladder-valve, which has permitted a small portion of gas to pass into the main beyond it, where the explosive compound was formed, and by the merest hazard, a neighbouring light has produced the calamity; therefore, in laying mains, when practicable it is always better to have a sheet-iron temporary valve. This is done by placing a thin sheet of iron between the spigots of two pipes at the point where the stoppage is desired, which may be clayed or cemented round to prevent the leakage of gas. The plate can be removed when requisite, and a temporary or permanent joint made with a running socket.

An erroneous impression exists that if a gas-holder were to be rent by accident, and the gas ignited, whenever the holder touched the ground, in the absence of pressure, that the contents would explode. This is incorrect, for, no matter the size of the opening, when the pressure ceased the flame would be extinguished; but from this moment danger would commence, as the portion of gas remaining in the holder would gradually issue and air take its place, so by degrees an explosive compound would be formed.

An explosive compound of gas and air, when under pressure, only ignites at the exterior of the pipe; but if the pressure be taken off the flame enters, and it explodes.

In illustration of these assertions we will relate a few experiments we entered into, in order to be convinced of some of the circumstances under which explosions take place. The most suitable and available vessels for the purpose were old tin-plate meter cases of the larger sizes. In the first experiment with a 50-light case,the gas was allowed to flow through for a considerable time, when the bottom plug was replaced and a light applied to the outlet. The gas then burned with a flame equal to the diameter of the pipe, and about 18 inches high, but this quickly diminished until it died out, or was extinguished. This was tried several times with the same result, thus proving that when gas is enclosed in a vessel, the moment the pressure ceases the flame is extinguished. But by allowing the vessel to remain some time, and afterwards applying a light, it was shattered to pieces; which arose from a part of the gas having gradually escaped, in the meantime air entering and combining with the remainder, formed an explosive compound.

Another similar vessel was again charged as before, but in this instance the bottom plug was left open, and on applying the light, the flame was considerably higher and more vivid than in the former experiments, caused by the gas by its lightness ascending, air entering by the lower orifice to fill the place of the gas. Gradually the flame became dimmer and dimmer, and at last changed to a deep blue, when it suddenly entered like an inverted cone, and explosion took place, shattering the meter case, and throwing its ends a distance of several yards.

On another occasion, on making a trial with a very small holder containing 2 feet of explosive compound, with a pressure of $\frac{5}{10}$ths, the gas issuing from a $\frac{1}{4}$-inch orifice, it ignited with a very intense blue flame; but on taking the pressure off the holder, and applying the light, explosion occurred, lifting the holder from its place, and throwing the water of the tank in every direction.

We need hardly say that these experiments require great care. Thin tinned iron vessels are sufficiently strong; and as the *débris* are thrown a considerable distance, too much caution cannot be exercised. When a cylindrical vessel is subjected to explosion, the ends generally give way, whilst the sides remain intact.

But if a further proof be necessary that an explosive mixture when under pressure does not ignite, it is furnished by the facts that hydrogen can be stored with safety under pressure, but will explode when released therefrom, as we experienced many years ago when experimenting with the apparatus employed for obtaining light by means of hydrogen impinging on spongy platinum. However, in any case, an explosive compound will not ignite through ordinary burners, as the holes are too small to permit the flame to pass. The reader may refer to the action of the Crossley gas-engine, in which, however, there is a stratum of gas, ignited at the moment the pressure is diminished, which confirms our views. We have dwelt particularly on this point, on account of a gentleman holding a high position in the gas profession, having expressed the opposite opinion.

The explosion of gas was formerly considered to be due to the hydrogen in combination therewith, which assertion was maintained by Sir William Congreve. However, it is now established that the richest gases are the most destructive when exploding.

An explosive mixture always possesses a very powerful odour of gas, which is sufficient to indicate to any one that a light should not be approached; and under these circumstances, when in dwellings, ordinary precautions only are requisite, above all, to have no lights near, and to open the doors and windows, the upper part of the latter especially, as gas by its lightness ascends, and will readily escape from there. The main tap should be closed, and a careful inspection made, when perhaps a tap will be found turned on, or an hydraulic joint without water, or some other defect which can easily be remedied. No one should ever apply a light where there is an odour of gas in the upper part of an apartment; many little mishaps have occurred through neglecting this precaution. Should there be any escape which can only be detected by flame, the gas ought to be turned off for two or three hours, and the other precautions being adopted, the light may be applied the moment the main tap is turned on; but it is always better and safer to detect escapes in dwellings without the employment of a flame, as for this object only a little more patience is required.

Meters are sometimes mysteriously destroyed by explosion, even when fixed in their places. The syphon plug when not sealed by water, and the tap of a burner being left open, are sufficient to permit air to enter and form the explosive compound, when a light being applied to an orifice without a burner, the flame enters, but does no injury beyond rendering the meter useless.

On the occasion of a fire occurring near a gas-works, the public journals formerly fell into error by assuming the contents of the gas-holders to be explosive, and dilated on the amount of damage that would arise from this event occurring, the public excitement being naturally much increased by this mis-statement. Gas-holders when in use, that is, containing ordinary gas, cannot by any means explode, even although the plates forming them were to be made red-hot by the flames; all that could occur is that the gas, when expanded by the heat, would issue in detached flames, but no explosion could take place. Another error is that when an edifice, as a theatre, takes fire, to turn off the gas to prevent explosion; which is done sometimes at the risk of putting the audience in darkness, to find their way out in the best manner they can. Nothing is more absurd; for supposing, at the worst, the fire to melt the pipes in the building, and the gas to issue, the same flame which melted the pipe would ignite the gas, so that under these conditions explosion is not possible. A good system is to have a valve, or valves, on the exterior of all public buildings of resort, which, in the event of a fire unfortunately occurring, can be shut off after all the people have left the building, so preventing the destructive effects of the flame should the gas ignite, and the loss of gas.

The most fruitful source of explosions in private dwellings is the hydraulic gasalier, which is often left for months or years together, without having a supply of water, and it often happens that persons are quite unacquainted with the danger which may occur from neglect on this point. This evil is further aggravated by the very small margin allowed by some makers of gas apparatus, for the evaporation of the water, and the manufacturer who produces a contrivance to supersede the hydraulic joint will be a public benefactor, and should be encouraged by every gas company in the world.

CHAPTER XXI.

VARIOUS METHODS OF PRODUCING LIGHT.

Water Gas—Hydro-carbon Process—Carburating Gas—Carburating Air—Electricity, how Produced—The Electric Light—Difficulties attending the Use of the Electric Light.

In 1824, the epoch when gas-lighting was thoroughly established, Ibbotson obtained a patent for producing hydrogen gas by the decomposition of steam, which he proposed to mix with tar or coal, in a state of ignition as a substitute for gas. A few years afterwards, Michael Donovan patented the means of enriching those gases which afford little light when burning, such as hydrogen "produced by the action of steam on coke heated to redness," and bringing it in contact with the liquid, or the vapour of spirit of turpentine, spirit of vegetable tar, coal naphtha, naphthaline, or similar substance heated or otherwise, and employing the combined mixture as the illuminating agent. Two years afterwards, Lowe applied the vapours of naphtha and other light hydro-carbons to enrich ordinary coal gas. And in 1847 Mansfield patented among other things, the "manufacture of bituminous substances which are so volatile that a current of atmospheric air, passed through them at ordinary temperatures, will when ignited, continue to burn with a luminous flame till all, or nearly all, such substances are consumed." Thus in the preceding we have the foundation of all the different processes, known generally by the terms of "water gas," "carburating gas," and "air gas," to each of which we will now refer.

WATER GAS.

When steam or the vapour of water is passed through a quantity of red hot coke, or a red hot iron pipe, it is decomposed, with an evolution of hydrogen and carbonic acid in the first case, and hydrogen only in the second case, as the other element of the water, the oxygen, unites with the iron. But when required for illumination the hydrogen is generally produced by decomposing the steam by means of iron. One gallon of water will yield 210 cubic feet of hydrogen gas, which although possessing considerable heating power is useless as an illuminating agent; although some years since it was successfully applied for heating stoves, when the burning jets of hydrogen were caused to impinge on pieces of platinum foil, and a cheerful-looking fire was produced.

About 25 years ago, the method of producing hydrogen by the decomposition of water and intermixing it with the gas obtained from rich cannel coal, caused considerable excitement. The process was supported by one of the first chemists and the most able engineer of the day, which induced the proprietors of the gas undertakings of Ruthin, Southport, Warminster, Dunkeld, also of many mills in Lancashire, to adopt the "hydro-carbon process" as it was termed, as a substitute for the ordinary method of manufacturing coal gas. The alleged superiority, and the adoption of the hydro-carbon process, caused many companies to make experimental trials on an extensive scale; amongst which were the Manchester and South Metropolitan, and during several months, the engineers of these establishments did their utmost to insure success; but experience and time proved the fallacy of the system, and the results of these extensive experiments only made evident the impracticability of the process in question. Whilst the towns mentioned, which were lighted by these means, instead of yielding profit, suffered one continuous loss.

The causes of this signal failure were various. Firstly: The production of hydrogen by the decomposition of water is very costly; under the most favourable circumstances much more fuel being required to produce a given quantity of gas from water than from coal. Secondly: Hydrogen when so produced and intermixed with rich hydro-carbons, forms merely a mechanical mixture—no chemical affinity existing between them—and, in consequence, on being submitted to diminished temperature, the hydro-carbons were deposited in the pipes before the gas reached the consumers' burners, whereby it was often so much impoverished and deteriorated as to be next to worthless as an illuminating agent. Thirdly: It was impossible to regulate the supply of steam in proportion to the heat of the retort where it was decomposed; hence on there being an excess of steam, nearly the whole passed off in a superheated state without decomposition, and was afterwards condensed into water; when under these circumstances, the rich gases were delivered without the proper quantity of hydrogen, and of course a beautiful light was the result. But on other occasions, when the water was successfully decomposed, the hydrogen being in excess, the gas would be exceedingly poor, and possess little illuminating power. Thus at one period the light would be of great brilliancy, and at another time of the worst description.

But one of the greatest objections was the cost of wear and tear. For although clay retorts were most suitable for the decomposition of water, on account of their being capable of sustaining a high degree of heat, yet in consequence of their porosity, and as the hydrogen was much more penetrating than coal gas, the loss by leakage was very great, which precluded their use. Iron retorts therefore only could be employed; and these, by the combined action of the heat, and the oxygen absorbed by them from the water, were speedily altered in their nature, and thickened to a great extent; presenting a large mass of non-conducting material, which not only increased the fuel account to an enormous degree, but in addition to this, the retorts were of very short duration. The expenses of the wear and tear, and the large quantity of fuel necessary for the process, added considerably to the many other disadvantages. Therefore it is not surprising that the irregularities and defects enumerated were fatal to the adoption of the process.

An argument suggested in favour of the hydro-carbon process was, that the hydrogen swept out the whole of the carbon, which, instead of being deposited in the retorts, was carried to the burners for consumption. This might probably be a consideration at that period, but the improvements in carbonising coal, by the employment of the exhauster, have reduced the deposit to an unimportant amount.

It may be stated that the zeal, energy, and perseverance displayed in endeavouring to carry this process to a successful issue, merited a better result; but the system was erroneous, and a striking instance of the highly successful experiment of the laboratory being commercially worthless when carried into practice.

Hydrogen gas has also been applied in conjunction with oxygen as a jet, which is caused to impinge on a cylinder of lime, of about one inch in diameter and the same height. A slow rotary motion is given to the lime, by which means the mass becomes incandescent and yields a bright intense light, called the lime light.

Hydrogen gas was employed by Gillard in another manner to produce light. For this object the gas issued from an argand burner surmounted by a platinum wire cage extending a little above the dull hydrogen flame; when on the wire cage becoming incandescent, it yielded an intense light simply by the incandescence of the platinum wire. The light by this process was neither *economical,* agreeable, nor useful. Narbonne, and two or three other small towns in France, were lighted for some time by these means, but the great expense of hydrogen caused it to be renounced. With the view of obtaining that gas economically, Gillard erected a cupola similar to those in iron foundries, which was filled with coke or charcoal, and when the fuel was ignited and brought to a state of incandescence by a fan or blower, all passage to or from the atmosphere was closed. Steam was then admitted at the lower part, which on passing through the volume of fuel was decomposed, when the hydrogen and carbonic acid with which it was impregnated, were withdrawn by an exhauster from the upper part of the cupola. Occasionally the supply of steam was stopped, and air furnished by the blower as before, to bring the fuel to the proper degree of temperature for the decomposition of the steam.

This plan, although much more economical than the retort system, did not succeed; the expense of manufacture was still very excessive. It may therefore be concluded that the production of hydrogen gas by the decomposition of water is neither advantageous nor economical, and whether applied to be intermixed with rich gases, heating platinum wire, or intermixed with oxygen to produce the hydro-oxygen or lime light, hydrogen cannot compete with coal gas.

CARBURATING GAS.

This process consists in passing the gas through a vessel or vessels containing light hydro-carbons, such as naphtha or spirit of petroleum, by which the vapours combine with the gas, whereby additional particles of carbon are communicated to it, which are held mechanically in suspension for a period, depending on the temperature of the pipes and the nature of the liquid. Thus the illuminating power of the gas is increased in proportion to the quantity of carbon vapours carried by it to the burner. At one period carburating gas was practically applied at several places; among others at the Penitentiary at Millbank; but the economy derived from it was more than counterbalanced by the trouble and inconvenience attending it.

The main difficulties existing against the carburisation of gas are, the irregular evaporation of the liquid; a portion of which, when first placed in the carburating vessel, is remarkably volatile, and passes off in abundance, requiring burners with small holes to prevent the formation of smoke. The vapour is liable to be condensed in the pipes, and by degrees, when the most volatile vapours have evaporated, the gas consequently not being enriched, a difficulty arises from the smallness of the burners; which, as already explained, give for the quantity of gas consumed, very diminished light.

The process of carburisation was tried for one or two years on the public lamps in the City of London; and, according to the estimates of the projectors, a considerable economy was to be effected, together with a great increase of light. To obtain these alleged advantages, it was necessary to change the ordinary burners, consuming 5 feet per hour, and replace them by others burning only 3 feet, which of course diminished very materially the account of the gas company; but, as the sequel clearly proved, was not an economy. The carburising apparatus being placed in the lanterns, were unsightly, besides throwing great shadows. The gas at one period, when supplied with fresh naphtha, issued with a smoky flame, rendering in a single night the glasses dirty and obscure; again in the course of a short time the naphtha was useless, when, on account of the very small burners, the gas was consumed under considerable disadvantage, and the light given was diminished to a serious extent. After a long trial it was renounced, on account of the difficulties it possessed and the absence of the economy anticipated.

There is, however, a process now before the public called *the Albo* Carbo system, in which solid naphthaline is employed, which may avoid the inconveniences attending the use of the liquid hydro-carbons.

Air Gas or Carburated Air.

There are few subjects connected with gas-lighting that have created so much attention from time to time as that under consideration. For since it was patented by Mansfield, at least a hundred patents have been obtained for precisely the same system. Several companies of more or less importance have been formed for carrying it into operation, the majority of which have failed, or were wound up, within a short period of their formation; and only within the last few years has any degree of success been attained with carburated air.

As already stated, this is prepared by a current of air passing through volatile bituminous substances, which when ignited burns with a luminous flame. In practice this is usually accomplished by a motive power meter actuated by a weight, attached to a cord; this cord is wound on a pulley which acts either directly or indirectly on the shaft of the meter wheel, and passes over another pulley situated at some height from the meter; the weight is attached to the end of the cord. The inlet of the meter is open to the atmosphere, and its outlet connected to the vessel containing the spirit of petroleum or other substance employed, and on the weight descending, the wheel of the meter is caused to revolve and so propel the air through the hydro-carbons in the vessel. This vessel is formed of one or several trays, each of which is charged with fibrous material in order to present a large surface for evaporation. It should be made of tin plate in order that little obstruction be offered to the caloric passing from the atmosphere to the spirit as it evaporates. By some, the air is caused to pass or bubble through the liquid, but we believe the proper method is to let it pass over its surface, when the vapours combine with it, and are consumed precisely in the same manner as gas; but for the purpose argand burners having very large holes are the best suited.

A system of apparatus is before the public which consists simply of a cylindrical vessel, generally made to supply twelve lights; this is divided into three or four compartments or shelves containing the spirit, over the whole of which the air must pass. The inlet for the air is open, and the outlet connected to the fittings. This vessel is placed in a locality cooler than the apartment to be lighted, and the current of air passing from the cool to the warm locality, is sufficient to give the desired pressure to carry the vapours and air to the burners, where the compound is consumed in argand burners, similar to gas. Thus by this apparatus no mechanical appliances, nor the attention they demand, are requisite; against this, however, there are some drawbacks, the most important of which is, that a locality cannot always be assured to be cooler than another, when of course the instrument is inoperative; besides, with this apparatus, on account of the low pressure obtained, argand burners only can be used.

Whenever coal gas is not to be had, air gas may be advantageously employed for lighting, and by which all the effects of coal gas are produced, and for that object all that is required where the motive power meter is used, is to wind up the weight which actuates it occasionally. The frequency of the operation will depend on circumstances; but under any conditions the distance of fall of the weight should be at least ample to permit of the lights burning the longest night without any interruption. Moreover, precautions must always be observed when charging the saturating vessels with the spirit, as this is of necessity very volatile, easily ignited, and when mixed with air is highly explosive.

THE ELECTRIC LIGHT.

The excitement that has existed at various times concerning the electric light, and the probability that it may at some period become antagonistic to gas-lighting, is sufficient reason for us to refer to the subject.

Beyond the *effects* of electricity little is known concerning it, and perhaps the simplest method of illustrating one of these effects, is by placing a silver coin on the tongue with a piece of zinc beneath it, when, besides the mere pressure of the two hard substances against the top and bottom of the tongue, no sensation is experienced; but the instant the two metals are caused to touch each other, or brought in contact by a piece of copper wire touching the two, there is a strong metallic taste which continues without interruption, which is due to the action of electricity.

If a plate of zinc be immersed in a solution of sulphuric acid, chemical action immediately takes place, when the oxygen of the water combines with the metal, whilst the hydrogen is liberated in numerous bubbles of gas. Thus the water is decomposed by the superior affinity of its oxygen for the zinc, and this decomposition continues until the sulphuric acid, which greatly facilitates the action, is exhausted by the combination of the sulphur with the zinc, forming, in connection with the oxygen portion, with the decomposed particles of water, soluble sulphate of zinc.*

When the surface of the zinc plate is well amalgamated with mercury, those particles of water and acid only in immediate contact with the metal are decomposed. The hydrogen gas collects in minute bubbles over the surface of the plate, but they do not attain sufficient size to detach themselves from the metal, and the plate consequently becomes coated with innumerable minute bubbles of hydrogen gas. This gaseous coating protects the metal from being further acted on by the acidulated water, and it would thus remain in the liquid unchanged for a length of time.

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* Bakewell's "Electricity."

A piece of sheet copper may be immersed in the same vessel without causing any alteration in the state of things, so long as the metals are kept apart, but the instant that the metals touch, a brisk action commences, and *electricity is produced.* The bubbles on the surface of the zinc are transferred to the copper, and rise rapidly to the top of the fluid; these are followed by continuous successions of bubbles of gas, all rising from the copper surface, as if the chemical action were taking place with that metal. It is the zinc, however, that is alone attacked, and being deprived of its protecting coating of bubbles, it continues to be converted into sulphate of zinc, until, as in the previous case, the free sulphuric acid is exhausted.

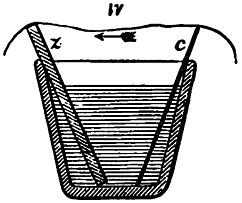

Fig. 71.

It is not necessary for the production of this effect that the metals should touch in the fluid. If the lower parts only of the plates be immersed, and the upper ends are brought together, the formation of bubbles proceeds quite as briskly as when the metals are in contact in the liquid. Neither is it requisite that the copper and zinc should be immediately connected. If the lower ends of a copper and of a zinc plate be immersed, and the parts out of the fluid be connected with a wire, as in the above diagram, Fig. 71, the evolution of bubbles from the copper surface will continue, though not so rapidly as before; the diminution in the action arising from the resistance which the wire offers to the passage of the stimulating force.

Preserving the order of arrangement shown in the figure, let the sizes of the plates be enlarged till the extent of surface immersed amounts to about fifty square inches. The evolution of gas from the larger surfaces will be greater than before, but not in proportion to their increased extent, for if the thickness of the connecting-wire, *w*, do not correspond with the increased capacity of the plates, the resistance it offers will diminish the effect. Let the wire be reduced to the size of a hair, and another remarkable phenomenon will be observed. The force is then much greater than can be freely transmitted through that thin wire, and it is developed in the form of heat. The wire will become red hot, and, if the action be energetic, will even be melted in the act of transmitting from plate to plate the peculiar power called voltaic electricity, by means of which water is decomposed, and light is produced.

The electricity generated by a single pair of plates or cell, possesses a very low degree of intensity. The quantity is only limited by the size of the plates, but no increase of size alone will add to the intensity of the force. Thus, though a pair of large zinc and copper plates, excited by diluted sulphuric acid, will fuse any of the metals, they cannot decompose a drop of water, because in the latter case the force is not sufficiently energetic to overcome the resistance of the fluid.

The most brilliant of the phenomena of voltaic electricity is the light evolved between two charcoal points. To exhibit this effect, a battery consisting of at least fifty pairs of copper and zinc plates, 4 inches square, is required. Two pointed pieces of the carbon deposited in the retorts, answer better than wood charcoal, which are fixed as shown in the engraving, each carbon point being connected with the opposite ends of the voltaic battery. The two points must first be brought into contact, and the electric current being thus established, the pieces of carbon, after being heated, may be gradually separated from each other to the distance of an inch and upwards, without breaking the voltaic circuit. The space between the points is occupied by the arch of flame called the electric light.

The action of this will be understood by referring to Fig. 72, which represents a wooden base. On this are secured two sockets; into these are cemented the two glass pillars with their mountings, the object of the glass pillars being to prevent the electricity escaping to the base. The two pieces of carbon are secured in their corresponding metal holders, which slide freely in two brass tubes. The wire, *a*, being connected with one end of the battery of 50 cells, as stated, and *b* in communication with the other end. On the battery being properly charged with dilute acid, electricity is generated; the two pieces of carbon are then caused to touch each other, when similar to the action on the very thin wire, heat is produced, and the carbons are separated as shown, when the space between them is occupied by the electric arc or light.

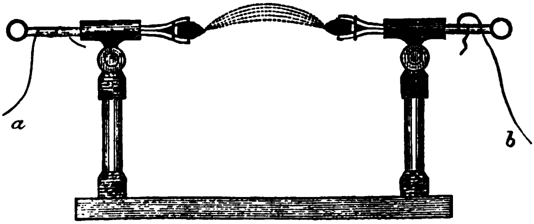

Fig. 72.

During many years the only method known whereby the electric light could be produced was by voltaic electricity, as described. But in the course of time it was discovered, that all the effects of voltaic electricity could be produced by permanent magnets, without any battery whatever.

To describe this, in order to render it intelligible would occupy more space than we have at our disposal; we may therefore briefly state that the method of obtaining electricity for the light at the present day, is by means of motive *power*, which causes a number of armatures to revolve at great speed in close proximity to a series of permanent magnets, by which the requisite electricity is obtained for the combustion of the carbon. The arrangement of the carbon has also been altered, but the cause and effects are like those already presented to the notice of the reader.

The question now arises, Is electric lighting likely to supersede gas? To this we answer that, in our opinion, for large squares, docks, and places of extensive area, where the light of a thousand candles or upwards may be required, electricity will eventually compete with gas; and, according to good and independent authority, when producing large masses of light the former is the cheaper. But an evil is, that when it is subdivided, electricity loses power very materially, as, according to Professor Thompson, on subdividing the power of 1,000 candles to supply ten different lights, instead of getting at each point the light of 100 candles, only the tenth part of that number is really obtained; and this loss by subdivision is fatal to the light under consideration, either for lighting dwellings, shops, and even the majority of streets.

Thus, assuming our opinion to be well founded, it is evident that the use of electric lighting will, under any circumstances, be very limited, on account of the few towns having the necessary large spaces or areas required to be illuminated. However, much remains to be accomplished by gas companies in order to prevent electricity acquiring the ascendancy; that is, by providing good burners and other facilities for consumers, in order that the maximum degree of light may be obtained from the gas. By giving every encouragement to the adoption of gas warming and cooking stoves, and the other numerous applications of gas. Lastly, in availing themselves of all improvements in the manufacture, with a view to the economical production of gas, by which means its price may be reduced, for as experience has proved diminished price always insures an increased demand.

varying state of the weather, whereby gas in any given locality is rendered more or less compressed or compact, according to the degree of atmospheric pressure arising from this cause; which, however, seldom varies more than 2½ inches at any particular elevation.

These influences of the atmosphere are ascertained by means of the barometer. This instrument is illustrated in its simplest form by taking a glass tube of about 33 inches long, having a bore of ⅛ or ¼ inch diameter, which is closed at one end and filled with mercury. This accomplished, a cup containing a portion of mercury being at hand, the open end of the tube is firmly closed by the finger. The tube is then inverted and held perfectly vertical, and its open end immersed in the mercury contained in the cup; when, on the finger being removed, the column of mercury falls to a point according to the state of the weather, or the elevation of the locality where the operation is conducted. Under ordinary circumstances, the distance between the level of the mercury in the cup and the top of the column is 30 inches; for this reason it is taken as the standard of comparison for gas, which column is supported entirely by the pressure of the atmosphere. If we suppose the tube and the cup to be fixed, with a scale of inches and tenths of inches attached to indicate the height of the mercury, then we realise the construction of the barometer. By these means the degree of compression that gas is subjected to, is known, and the proper corrections made to reduce it to the given standard.

The increase or decrease of volume is about $\frac{35}{10000}$th part for every variation of one-tenth of an inch of mercury. But in any augmented volume occasioned by diminished atmospheric pressure, as all the atoms of the gas and hydro-carbon vapours are separated from each other proportionably, the smaller volume contains precisely the same amount of illuminating agents as the larger, the *increase* of volume being accompanied by a corresponding *reduction* in the quality of the gas; on the other hand, by increased atmospheric pressure, the density of the gas and the illuminating power of any given quantity are augmented. It therefore follows that according to the height of a town above the level of the sea, so will the yield of gas per ton of coal, be proportionably increased, and the quality of the gas reduced.

Now, on referring to the table, page 237, we learn that the influence of the atmospheric pressure, as indicated by the barometer, acts in a marked manner on the volume of gas at any given temperature. Thus a volume of gas which is equal to 1,033 feet at 31 inches pressure, becomes compressed into a volume of 933 feet at 28 inches atmospheric pressure. These facts, therefore, show the necessity for making these corrections in order to ascertain the real and true volume of gas at the defined standard.

There is, however, another controlling influence which affects the illuminating power of any description of gas, that is the elevation of the locality above the level of the sea. For instance, Munich is about 1,700 feet above the sea, and, according to Dr. Frankland, "a description of gas that would give the light of 100 candles at London would there give only the light of 91 candles; and if the same gas were burnt at Mexico, which is about 7,400 feet above the level of the sea, it would give the light of 61½ candles only. These calculations are quite independent of the considerable change of volume; if this be taken into account the difference becomes much greater. Equal volumes of gas burned in London and Mexico would give quantities of light which would bear the proportion of 100 to 46·2."

Other conditions which will affect the illuminating power of the gas are, the accidental admixture of atmospheric air, to which reference has been made under the head of Exhausters; also the pressure of carbonic acid gas, of which one per cent. intermixed with coal gas will reduce the illuminating power of the latter to the extent of about 7 per cent. Barometrical changes also influence the yield of gas from any given quantity of coal, both by their action on the temperature of the retorts as well as by their pressure.

SPECIFIC GRAVITY OF GAS.

At one period the specific gravity of gas was regarded as an indication of its illuminating power. This system has, however, long been discarded as erroneous, except when in the hands of a good chemist, who is able to determine all the various constituents of the gas. In order to demonstrate this it may be remarked that carbonic acid is three times heavier than 20-candle gas, therefore a small portion of the former will augment considerably the specific gravity whilst it materially deteriorates the luminosity of gas. However, as the weight of any given volume of gas is sometimes determined by its specific gravity, we give the generally accepted rule for that object.

Rule.—Multiply the quantity in feet by the specific gravity, and strike off the three right-hand figures, then multiply the remainder by the decimal ·0753, and strike off the proper decimals, when the remainder is the weight in pounds. Thus, if 90 lbs. of coal give 400 cubic feet of gas, of specific gravity 420—then 420 × 400 × ·0753 = 12·65 lbs. of gas.

The following comparison of the specific gravity of gas with the illuminating power as shown by candles is an average deduced from the results of the best experimenters:—

No. of Candles.		Specific Gravity.
12	equal to	·400
14	"	·425
16	"	·450
18	"	·475
20	"	·500
22	"	·530
24	"	·560
26	equal to	·600
28	"	·610
30	"	·670
32	"	·700
34	"	·730
36	"	·770

Analyzing Gas.

We now come to the means of analyzing gases, and intend to indicate the method which can be applied for that purpose, such as any one with ordinary intelligence can employ. For this operation a Cooper's tube is the main essential, which consists simply of a glass tube of about 20 inches long and ½ inch internal diameter, having one end closed, and the other end open and bent in the form of an inverted syphon, as represented in the annexed figure. A graduated scale is marked on the tube, commencing from the level of the open end and continued upwards for about one-fourth of the capacity of the tube. A tall tank or vessel is also provided and filled with water in which the whole of the Cooper's tube can be immersed in order to equalise the temperature. When operating with this tube it is first filled with water; it is then charged with the gas and held in a vertical position, as shown in Fig. 73.

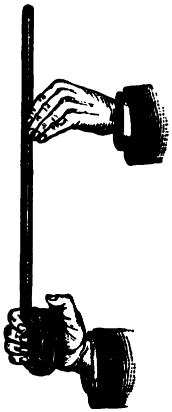

Fig. 73.

The methods indicated by Dr. Letheby to ascertain the presence of certain gases in any gas are as follows:—

Carbonic Acid. — To ascertain the quantity of this existing, a volume of gas is passed into an ordinary Cooper's tube previously filled with water, and after allowing the tube to stand in the vessel of water for a few minutes, so as to equalise its temperature, the volume of gas is read off. A piece of caustic potash is then let up into the tube and allowed to dissolve in the water, the tube being kept in motion with the thumb firmly placed over the opening, so as to dissolve the potash without allowing any of the gas to escape. When the potash is dissolved the tube is returned to the vessel of water for the purpose of equalising its temperature, and after a few minutes the volume of gas is read off; the loss, if any, is due to carbonic acid.

In performing this as well as the other experiments, gas is allowed to pass by means of a small flexible pipe, so as to fill the tube to the point 100, and from this point upwards the scale indicates the volume. Thus, if we suppose 5 per cent. of carbonic acid to have existed in the gas, after the operation, the tube will contain only 95 volumes of gas, which again may be analyzed by the means hereafter indicated.

Oxygen.—To determine the presence of this, a little pyrogallic acid, about half a thimbleful, in the condition of dry powder, is next to be put into the potash solution in the tube, and having placed the thumb over the orifice of the tube as before, it is to be well shaken, so as to bring all the gas into contact with the alkaline solution of pyrogallic acid. If oxygen be present, the solution will acquire a brown colour, and after returning it to the equalising vessel of water, the amount of absorption can be read off, which is due to oxygen. When using these tubes for the analysis of gas, the greatest care must be taken to prevent the escape of gas or the access of air, and the temperature of the gas must always be equalised by sinking the tube in the vessel of water before the volume of gas is read off. With a little practice all these conditions may be easily secured.

Condensible Hydro-carbons.—These are freely absorbed by chlorine, bromine, and fuming sulphuric acid. If chlorine be used, as was the practice of Dr. Fyfe, the tube must be kept in the dark, or it will combine with hydrogen and light carburetted hydrogen, and so give false results. Bromine, however, has the property of combining with the hydro-carbons without touching the other constituents of coal gas; and if it were not that it forms ethereal compounds, which diffuse vapour through the gas, and so affect its volume, the results would be very trustworthy. However, they are sufficiently reliable for common purposes. To determine these, a known volume of coal gas is passed into an ordinary Cooper's tube, and having equalised its temperature and read its volume, a single drop of bromine is put into the water at the bend of the tube, when, on closing the tube with the thumb, the gas and bromine water are agitated with just enough violence to diffuse the vapour of bromine throughout the tube. After standing for five or six minutes, and observing that there is still enough bromine to colour the gas, a small piece of caustic potash is added, and again the tube is closed and agitated. The tube is then referred to the equalising vessel, and when the temperature is restored, the absorption is read off, which is due to carbonic acid and condensible hydrocarbons. As the amount of the first has already been determined, the volume of hydro-carbons is easily obtained.

For further information on this subject, as well as a greater amount of detail relating to the testing of gas than our space permits, we recommend the reader's attention to Hartley's "Gas Analyst's Manual."

CHAPTER XXIII.

PUBLIC LIGHTING.

Oncrous Contracts—Concessions—Various Systems of Public Lighting—Effects of Different Latitudes—Lamp Regulators—Average Meter System—Street Lanterns.

LIGHTING the street lamps, or, as generally termed, the public lighting, is frequently unremunerative to gas companies, and in the majority of cases in the United Kingdom little profit is attached to it. Sometimes this arises from an absurd contract having been entered into by the gas company, or the proprietor of the undertaking, when first establishing the works, in order to secure the privilege of supplying the town; and we have known companies, both at home and abroad, to contract for the public lighting on such conditions as to result in a serious loss, which was well understood at the time, but they relied on recouping this loss by the high prices charged to private consumers.

This, although a very common system at one time, was decidedly wrong, as by it the gas consumers were taxed heavily in order to light the town or other locality, and by which the general public profited. According to some contracts, the gas company is bound to light several buildings gratuitously, and in one or two instances, illuminating the town clock is at their charge.

In the days of competition, projected new enterprises would undertake to light a district in opposition to an old-established company, for a short term of years, at a mere *nominal* charge: but at its expiration, after having laid their mains throughout the locality, the new company would demand a higher price, when the authorities, rather than submit to the terms, have lighted their districts by naphtha lamps, which were then coming into use. In very recent times, when the local authorities of certain towns have imagined the price demanded by the company to be extravagant, they have also resorted to paraffin as the means of illuminating their streets, but the inconveniences attending this have compelled them to make the necessary investigations, when, as a rule, the price asked by the company has been found to be reasonable, and has been accepted.

The system of granting concessions, or exclusive privileges for lighting towns and cities during a certain number of years, is very generally adopted abroad; and in some of these places, where the necessary capital can only be had from a foreign country, and where the people are desirous of having their town lighted with gas, under these conditions frequently very liberal terms are ceded to a projected company, not only as regards the price of gas to the consumers, but also in the number of lights, as well as their price.

In places where these concessions are granted, very often most onerous clauses are inserted in the contract, such as the extinction of any public light which is reported by a local official, to be visited by a heavy fine; or should any light be reported as inferior in power, a fine is also inflicted. This system is carried to such an extent in some places that the fines paid by a company are sufficient to pay a fair dividend on the capital employed in lighting a small town in England. These concessions are usually granted for a term, in some cases as much as fifty years, at the end of which period the town generally reserves to itself the right of purchasing the works, as valued by arbitrators named on each side.

Formerly, in some places, the established price of gas was such, that on the introduction of petroleum lamps it was tantamount to prohibiting the use of gas. In several countries, even at the present day, in important seaport towns, where coal costs but little more than in some parts of England, 18s. and 20s. per 1,000 feet of gas are by no means uncommon prices, and the cost of the public lamps is proportionably high.

It may be observed, however, that there are numerous controlling influences which govern the operations and the results of gas companies. The first and most important of which is the amount of capital; next, the management; likewise the consumption, both public and private; and even with the high prices stated, from which of the causes it may arise we will not pretend to say, but there are many companies that do not pay even a moderate dividend.

The arrangements for lighting towns, so far as regards the number of hours, are various. Thus, in many cities and large towns, the whole of the public lamps are lighted at sunset and extinguished at sunrise, every night, or an average of about 4,000 hours per annum; which, price for price, is of course the most profitable system for a gas company. By another arrangement, the lamps are not lighted during the five or six nights of full moon and those immediately preceding and following it.

Again, according to another system, every hour of moonlight throughout the year is taken advantage of, all the lamps being lighted in its absence, but are extinguished when the moon rises. On the night of full moon and the two nights before and after, they are not lighted at all, whilst on five nights of the month, when the moon is not visible, the streets are lighted from sunset to sunrise.

By this plan the average number of hours is about 2,000 per annum. However, it is attended with a considerable degree of trouble, on account of the great irregularity of the hours. To illustrate this, the first night after the full moon the lighting is of the duration of one hour only, and this increases each night until it is continued the whole of the night. It then decreases each night as the moon rises, until the period when the lamps are not required at all.

In some small towns the lanterns are removed, and the public lighting is dispensed with during six months of the year, and is then only employed, the moonlight nights excepted, until eleven or twelve o'clock. Besides these there are no doubt other systems of contracting which are beyond our knowledge.

The operations of a gas company are of course materially influenced by the contract adopted for the public lighting. Hence we find, as observed by the continuous method, the streets are lighted about 4,000 hours; whereas by the last-mentioned plan the number of hours does not exceed 600 or 700 per annum, and the plant is necessarily augmented considerably for these few hours. But the arrangement which influences most the magnitude of the gas store is where the lights are required for five or six nights in succession, and afterwards their consumption gradually diminishes, until for a corresponding number of nights no gas whatever is consumed by the public lamps. Under these conditions the storage must be very large, in order to permit the carbonizing operations to be continuous, and to keep up the supply when the heavy lighting occurs.

The capacity of the gas storage, and indeed the whole of the plant, is also materially influenced by the latitude of the city or town where the works are situated. For instance, in some tropical cities and towns the day and night are of almost uniform length through the entire year, in some places with a variation of two or three minutes only, the sun rising at six o'clock in the morning and setting at the same hour in the evening. But beyond the tropics, both north and south, as we approach the poles, a considerable degree of irregularity in the hours of daylight and night occur; and in the most extreme points where gas-lighting is employed the longest night or day is of about seventeen hours' duration. Thus, under the same conditions, say for continuous lighting throughout the night, a works for a given "make" would be required much smaller for a tropical town than for one in the north, where the whole of the plant is only in active operation during six or eight weeks in the year. Hence we learn that the table which is frequently met with in works on gas, which professes to give the number of hours the public lamps are lighted during each month of the year, can only be applicable to towns in one particular latitude.

According to the care observed in giving a proper supply to the public lights, so will any company's interests be affected. Thus, if the quantity contracted to be supplied to each lamp be, say, 5 feet an hour, and through the negligence of the employés, 6 feet are consumed by each burner, it is then obvious that a serious loss must be experienced. This at one time was to some extent excusable, but with the various descriptions of lamp regulators at our command at the present day, the desired supply to the public lamps, whether consuming 4 feet, 4½ feet, 5 feet, or other similar quantities, can be assured within a small percentage; and as the variation in the instruments is both against and in favour of the company, the aggregate gives a very close approximation to the exact quantity consumed.

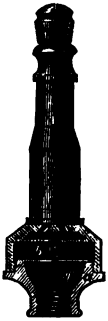
Fig. 74.

There are various kinds of lamp regulators, the diaphragm description, of which already mention has been made, also the rheometer, and disc regulator, all of which are adjusted to deliver any definite quantity of gas; and a further advantage they possess is that the pressure is reduced to the point at which the gas yields the greatest amount of light.

The regulator called the rheometer consists of a small bell, with its corresponding conical valve working in its *seat,* which is attached to the outer case. The case contains a quantity of glycerine, in which the bell works.

Hence the bell being acted on by the pressure, closes the aperture of the valve, and thus supplies the quantity of gas for which the instrument is adjusted.

The disc regulator is also well adapted for street lamps. This consists of one or two discs, according to the method of the manufacturer, inclosed within a cylinder, and so adjusted that, whilst the disc moves with freedom, only a very small portion of gas can escape at its periphery. Attached to the disc or discs, is a valve, the action being similar to the diaphragm regulator described; indeed the disc replaces the diaphragm. The Borradaile regulator is shown half size in section, in Fig. 74. *a* is the outer case, *b* the disc, which floats freely in its cylinder when submitted to a heavy pressure, and closes the aperture at the top of the cylinder *c*, whilst the orifice in the centre of the disc is made to deliver the necessary quantity. These regulators have only been introduced within the last three or four years, since which period they have come into very general use, alike in the Metropolis as in the provinces, and fulfil all the desired requirements, whilst their cost is moderate.

With lamp regulators no practical difficulty is experienced in adjusting the supply of gas to any desired quantity; moreover, by their use, the pressure of the gas is reduced to that degree, when the maximum amount of light is evolved by the gas, and any irregularities in the flame, by an increased pressure from the works, are prevented.

The system of applying meters to the public lamps has been tried by several gas companies as well as by parish and other local authorities. In some instances a separate meter has been attached to each lamp, but more generally the average meter system is adopted; that is, instead of a meter being attached to every lamp it is attached to every twelfth lamp, and by the indication of this the average consumption of the others is determined.

The meters employed for the purpose are by preference wet, which are often made expressly, of larger diameter and much narrower than the ordinary three-light meter, although of the same measuring capacity. Each of these meters has its dial on the top, and is enclosed in a cast-iron box; thus on opening the box the index can be observed. Its inlet and outlet protrude from the two sides of the box. Means are provided for charging the meter, as well as to allow any excess of water to flow from it. When placing these meters an excavation is made near the base of the lamp column of a depth and size sufficient to receive the cast-iron box containing the meter, and leaving a space of a few inches between the top of the box and the level of the paving. The meter being placed, it is connected to the supply service which is continued to the lamp, when the whole is covered by a cast-iron plate let into the footway or pavement.

This system has been adopted by a few parishes in the metropolis, who claim to effect some economy by it; which, however, we believe to arise from the extra care observed with the burners, both as regards the quantity consumed as well as in the hours of burning. Before the application of the lamp regulator such a plan might have been desirable, but with the recent marked improvements made in that instrument, in our opinion the lamp meter is unnecessary.

Recently some improvements have been introduced in the construction of the street lantern, and not before they were required. Foremost among the absurdities retained is the method of fixing the glass in the lantern frame by means of putty, which has outlived the epoch, when the lamplighter used to run up a ladder to light or extinguish a burner, which he could do with a fiftieth part of the labour by the lighting rod. On the Continent the means of securing the glasses in a lantern with putty is quite unknown, and that material might be necessary were it required to prevent air passing. The method there generally employed in making, glazing, and fixing lanterns, is certainly preferable to the English system, which will be understood by Fig. 75, representing an ordinary street lantern. At each of its four corners is soldered a

¼-inch round iron wire of somewhat greater length than the height of the lower part of the lantern. These wires are screwed at each end for the purpose of receiving the brass knobs shown at the top and bottom of the corners. The frame is made in the usual manner, but at each corner is a groove formed of tin plate of about ⅜ inch deep and of the width to receive the glass, which is generally 22 ounce. The glass being cut to the size is placed in its corresponding groove, when it is secured by a thin piece of lead, which is soldered to the top of the frame. The door is glazed in a similar manner. For the top of the lantern the grooves are placed on the outside, the glass is introduced at the bottom, and retained in its place by two thin pieces of soft lead soldered beneath the glass, which are readily bent over to hold it in its position.

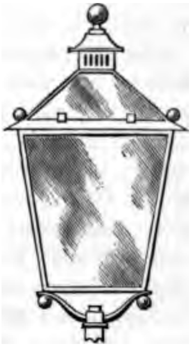

Fig. 75.

By these means the use of putty is avoided; the glasses can be cleaned with the same facility as when puttied, and in the event of a broken glass, another can be replaced in an instant. A great improvement recently introduced into some of the London lamps is to make the tops of white opal glass, which, whether viewed in the daytime or by gas-light, is far superior to the clear glass; moreover, it serves to reflect the light on to the pavement.

The unsightly iron frames which are used for our street lamps, and are sufficiently strong to carry a hundred times the weight they support, are also superseded by the French *croisillon*. This is a cast-iron cross-piece, having a hole in the centre sufficiently large to allow it to be placed on the lamp column, which effected it is secured by a set screw. The croisillon is shown in elevation in the last engraving beneath the lantern. Its arms are about ½ inch thick, each terminating with a button, pierced with a small hole, the four holes corresponding with the wires forming the frame of the lantern. Thus the upper is secured to the lower part of the lantern by screwing the four knobs on the top, and on the lantern being placed on its croisillon, it is secured by the four knobs at the bottom.

Other advantages of this system consist in the facilities afforded for package, as all the tops or bottoms of the lanterns "nest" together. The glasses are sent separate, and a lantern is glazed in a few minutes. Lastly, the unsightly wrought-iron bracket, so often met with in towns of the United Kingdom, should give place to others of a more ornamental character, the cost of which would be unimportant. In short, the great improvements introduced in the designs of our gas establishments, in our public buildings and streets, as well as the ornamental character of gas fittings, chandeliers and globes in our dwellings; demand an improved appearance, in the lanterns, brackets and columns, in our thoroughfares, which would undoubtedly contribute to the further progress of gas-lighting.

CHAPTER XXIV.

CONCLUDING REMARKS.

The Various Alterations made in Gas Manufacture—Visits to Various Gas-works, and their Results—The Evil Effects of the Dip-Pipe—Quiescent State Necessary for the Purification of Gas—Propelling Gas through Mains—Compressing Gas in Holders.

SINCE the first issue of this work twenty-seven years ago, a marvellous change has taken place in the manufacture, distribution, and the numerous applications of gas. In that period, by the general introduction of clay retorts, the system of carbonization has been materially improved, and by which the yield of gas from a given quantity of coal has been increased at least 17 per cent.; as with iron retorts the average yield was 8,500, whereas with clay retorts it is 10,000 feet per ton of coal carbonized, which is accompanied with a considerable reduction in the fuel account, as well as in the expenses of labour, and wear and tear of the apparatus.

The magnitude of works has increased at least tenfold, and of course the consumption of gas has followed in the same rate.

The "unaccounted" for gas or loss by leakage, which was then estimated at from 25 to 30 per cent., is now on the average not more than 7 or 8 per cent., and in some cases is as low as 4½ per cent.

The value of the residuals, and particularly ammonia, is better appreciated, and that which was formerly allowed to flow to the sewer or sea, constitutes an important item in the profits of a company. On this point, however, much remains to be accomplished.

The false means of evaluing the illuminating power of gas by its specific gravity has been discarded, and a positive method of arriving at that knowledge adopted, and proper burners and glasses are now being introduced, by which the full amount of light is obtained from the gas. These and innumerable other improvements have been introduced in the period stated, and no doubt the future editor of this work will in due course have vastly more important matters to lay before the notice of the members of the gas profession.

The result of these changes has been the more extended use of gas; and gas property which at the time we first referred to, was of a very doubtful character, has now become one of the most secure and profitable investments, and may it long continue so.

During the progress of the present volume the author has had occasion to visit about one hundred gas-works of various magnitudes, from the largest in the world at Beckton, to the diminutive establishment producing one million feet per annum; and he avails himself of the present opportunity of thanking the various engineers and managers for their universal kindness, in their reception, and candour in making known their various systems and ideas.

Our connection with the art of gas manufacture commenced more than a generation ago — a period when engineers, or superintendents, often lacked an ordinary rudimentary education; and with their restricted views, appropriated to themselves a degree of learning and knowledge, which like the mysteries of the alchemists were kept profoundly secret; and to this end in the majority of gas-works no official was permitted to pass beyond the porter's lodge, the point of separation between the administrative and the productive. Whereas the gas-engineer or manager of the present day is of a very superior order, possesses more extended views, and has a good knowledge of all that concerns his *métier*. Among them many have, in a manner of speaking, been educated in a gas-works from their childhood; others have followed some mechanical business which adapts them to their career; and not a few have received excellent education, are fair chemists, and have been articled for a number of years to some gentleman who holds, or has held, a superior position in the gas world. Therefore, under these circumstances, it is not surprising to find the present generation of gas-engineers so far superior to their predecessors, and that the urbanity to which we have referred should have been a natural consequence.

The result of these visits and the interchange of ideas, has confirmed us in most of the views we have expressed in this work, except so far as regards condensation and the production of naphthaline; on these two points especially there appears to be some diversity of opinion. While, however, a few engineers still adhere to the method of sudden condensation of the vapours passing off with the gas, the larger majority adopt the system of gradually effecting that process. Nevertheless, by the observations we have made we are more convinced than ever that rapid condensation is conducive to the formation of naphthaline; but by what means that compound is formed besides the explanations we have endeavoured to give, at the present day is shrouded in mystery.

The evil effects of the "dip" in the hydraulic main, by absorbing the hydro-carbons and impoverishing the gas, is much more generally recognised than we anticipated; as we have recently heard from some of our most intelligent and eminent engineers the beneficial results both in the quality and in the quantity of the gas obtained from a given quantity of coal, by the means they have employed to dispense with the dip; which we are disposed to believe will lead to most important beneficial results to the rising generation.

Among the gentlemen who are giving the question their serious attention are Messrs. Tangye Brothers and Holman, G. Livesey, Ganden, and Wates, each of whom has a special contrivance to attain the desired object.

During our visits at various works, we were surprised at the large purifiers adopted, which generally exceed the dimensions herein defined. This, however, if we disregard the capital employed, can only be beneficial, inasmuch as gas in a state of repose, deposits its impurities with greatly increased facility; and should evidence be required to confirm this assertion, it exists in the fact that when gas is passing rapidly through a very small purifier, it is not purified. Nature requires repose in numerous of her operations, thus a tank containing water, when subjected to any vibration, the impurities continue suspended in the liquid, but on permitting the liquid to remain in a quiescent state they are deposited. Again, when water is in rapid motion, it will not freeze unless the temperature be exceedingly low, but the instant it is in a tranquil state, the crystals are rapidly formed, and a part of the water assumes the solid state. And we venture to believe that both these illustrations point to the necessity of having the gas in a state of repose during its purification in the ordinary sense of the term, that is when being deprived of its sulphuretted hydrogen, carbonic acid, ammonia, and sulphur compounds.

Moreover, we believe that any sudden action by which these impurities are eliminated, must be accompanied with a corresponding evil. We were led to this conclusion on a recent occasion, on observing an apparatus in which the ammonia was suddenly removed from the gas, when in the course of six months only, the connection, an 18-inch pipe, was half filled with naphthaline and tar.

Among the innovations being introduced into the manufacture of gas, are the means of heating the furnaces with the gases generated by the combustion of coke, which is the subject of extensive experiments at the South Metropolitan Gas Works and promises to be highly successful.

On a recent visit to those works we were surprised at the extraordinary success of the brick retorts which are exclusively employed there.

Another important application of gases is made by Messrs. George and Anthony Bower in their improved process of preserving iron, which differs from that already described. The following is the method of procedure now adopted, and which answers most satisfactorily:—The articles are first of all heated, and acted on for a certain period by the products of combustion largely mixed with air from a peculiarly constructed furnace burning slack or small coal. In this way a coating of magnetic oxide is formed close to the surface of the iron, but this is often slightly covered with red oxide. The admission of air to the furnace is then so arranged by a suitable apparatus that a stream of carbonic oxide is passed over the articles for a short time, when the red oxide is very speedily reduced to magnetic oxide.

The indefinite method of selling coke by the sack without strictly regarding its dimensions, is now superseded at many works by the adoption of the measure mentioned in page 80. When referring to the quantity of coke employed and produced, in the preceding pages, it is always intended to be the heaped bushel, of three to the sack; but heap measure is no longer legal, thus the sack becomes four strike bushels. Many engineers prefer to sell coke by weight, others prefer to sell by measure. There are difficulties attending the two methods; one the amount of humidity absorbed by the coke, the other the variation in the quantity according to its size. For instance, twelve sacks of coke, as ordinarily obtained from the retorts, when broken to the size of a small orange, as practised by some companies to facilitate its combustion, is reduced to ten sacks.

At various times it has been suggested to propel the gas through the mains; Clegg at one period entertained the idea of making gas at Newcastle, and propelling it through tubes to London by means of exhausters placed at intermediate stations. The practicability of this was never questioned, but there arose the important consideration how to dispose of the coke resulting from the carbonization; for, as is well known, the value of that important residual, depends materially on the position of the works where the coke is produced. Thus in populous neighbourhoods coke finds a ready market, but from its fragile nature it is deteriorated materially, by transport; both of which circumstances were obstacles to the realisation of Clegg's project. However, the method of propelling gas through mains has been forced on the attention of The Gas Light and Coke Company, by reason of their two 4-feet mains being insufficient for the supply; and in order to avoid the expense of a third main, arrangements are now being made, to fix the necessary apparatus for the purpose of forcing the gas to London. It is anticipated that a pressure of 12 inches at Beckton will be sufficient to meet all requirements, or at least for a time. Afterwards probably the pressure will be materially augmented, and eventually it is highly probable that gas-holders will be formed hermetically tight, similar to steam-boilers, and the gas compressed to any required degree, to be distributed as occasion may require. Circumstances favourable to this system are the present cheap rate of motive power, the facilities existing for making the apparatus, and the fact that with closed holders, 30 cubic feet may be compressed into the space of one foot. Thus according to this plan a holder of little more than a capacity of 30,000 feet would contain 1,000,000 feet of gas.

However, in developing this system it would probably not be necessary to compress the gas to less than one-tenth of its ordinary volume, which would demand a forcing power equal to 150 lbs. on the square inch. The nominal value of breeze which could be employed as fuel to produce the power is favourable to this process.

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	Make per House.	Illuminating Power.	Make per Ton.	Make per Mouthpiece, 24 Hours.	Quantity.		Percentage of Cannel.	Average Cost per Ton.		Average Cost per 1,000 Ft.		Cost per 1,000 Cubic Feet.	Cannel and Coal.		Wages Account.	Interest, Depreciation and Wear & Tear.	Total Expenditure per 1,000 Feet.	
	Cubic Feet.	Candles.	Cubic Feet.	Cubic Feet.	Tons.	Cwt.		s.	d.	s.	d.	d.	s.	d.	d.	d.	s.	d.
FOULIS	9,105,716	18·05	10,266	6695·4	886	18	66·75	12	9·6	1	2·97	Wages, 2·905 *Ponies, 0·105 3·01	1	2·97	3·01	0·383	1	6·36
WEST..	**10,738,200**	**18·19**	**11,709·5**	**8948·5**	**917**	**1**	**68·45**	**12**	**11·2**	**1**	**1·25**	**1·68**	**1**	**1·25**	**1·68**	**0·236**	**1**	**3·16**

* The ponies are used to draw the scoops to the machines in Foulis's system.

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Bremen	150,000	,,	,,
Buxton Local Board	250,000	,,	,,
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Driffield Company	100,000	,,	,,
Goole Company	250,000	,,	,,
Glossop Company	300,000	,,	,,
Holywood Company	125,000	,,	,,
Heywood Local Board	600,000	,,	,,
Leeds Corporation	2,000,000	,,	,,
Leominster Company	150,000	,,	,,
Maidstone Company	1,000,000	,,	,,
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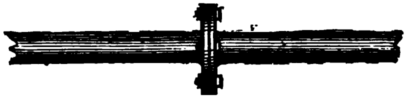

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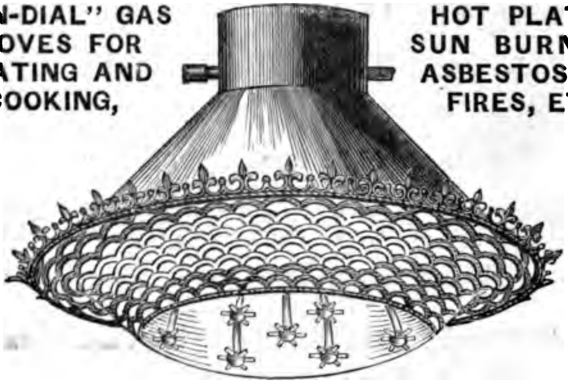

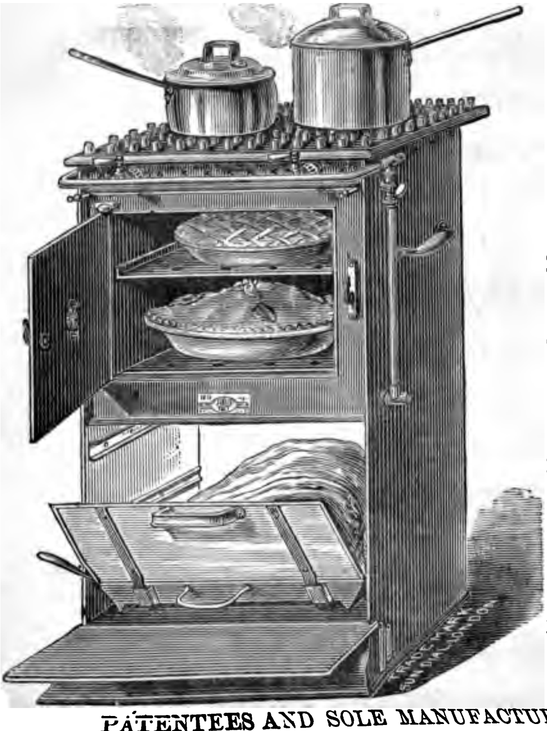

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Fig. 224.

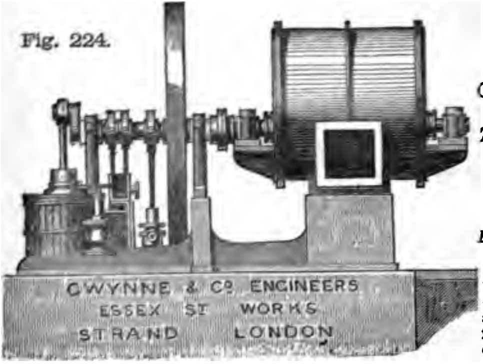

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Fig. 225.

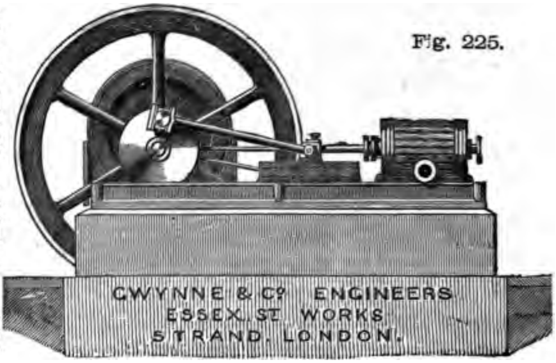

Fig. 224 represents one of the large Gas Exhausters erected at the Bromley Works of the Gas-Light and Coke Co., capable of passing 210,000 feet per hour.

Fig. 225 represents one of the large Gas Exhausters erected at the Commercial Gas Works, capable of passing 210,000 feet per hour, and has been at work 8 years satisfactorily.

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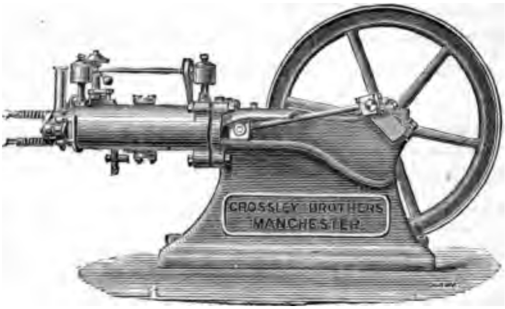

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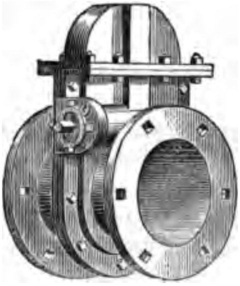

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